NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC

January 28, 2002

Vehicle Performance Study

by
Dennis Crider

A. ACCIDENT

Location:	About 14 miles South of Honolulu Hawaii
Date:	February 9, 2001
Time:	About 23:42 Universal Coordinated Time
NTSB#	DCA01MM022

B. GROUP

Dennis Crider
NTSB
Washington DC

Victor Gavin
NAVSEA
Washington DC

CDR Tom Stanley USN replacing LCDR Rick Stoner USN
Com Sub Pac
Pearl Harbor HI

C. SUMMARY

On February 9th, 2001 the USS Greeneville, a Los Angeles class attack submarine collided with the Ehime Maru, a Japanese fishing training vessel, about 14 miles South of Honolulu Hawaii. The Ehime Maru sank. Nine persons aboard the Ehime Maru were missing and presumed dead.

D. DETAILS OF INVESTIGATION

Introduction

This report describes the motion of the USS Greeneville, the Ehime Maru and other surface vessels that may have been tracked by the USS Greeneville's sonar near the time of the accident. Data recorded from the USS Greeneville's sonar and fire control systems (the system responsible for calculating the range, course and speed of sonar targets) are also covered. Submarine speeds in excess of 25kts and depths below 800 ft are classified and thus not included in this document.

Radar Data

Radar data were obtained from the Air Force 84th Radar Evaluation Squadron (84th RADES) and the FAA. These data were sorted to leave un-reinforced primary radar targets in the area of the accident. That is, radar returns not near the collision and from aircraft using transponders were removed. The remaining radar returns were plotted as a function of time to identify radar tracks. As shown in figure 1 and 2, tracks having the characteristics of surface ships (slow speed, no aircraft transponder return) were found in the data from the Honolulu airport surveillance radar. The Honolulu airport surveillance radar (HNL) is an ASR-9 located at 21:19:03.82 N and 157:55:41.48 W. The antenna elevation is 68.1 ft with a magnetic variation of 10.5 degrees East. Azimuth & Range data was converted to East and North position from this antenna using the tracks program. North positions vs. time for the radar returns are plotted in figure 1. East positions vs. time for the radar returns are plotted in figure 2. Note that one track visible in the North vs. time plot ends at 23:43 UTC (this will be established later as the time of the collision).

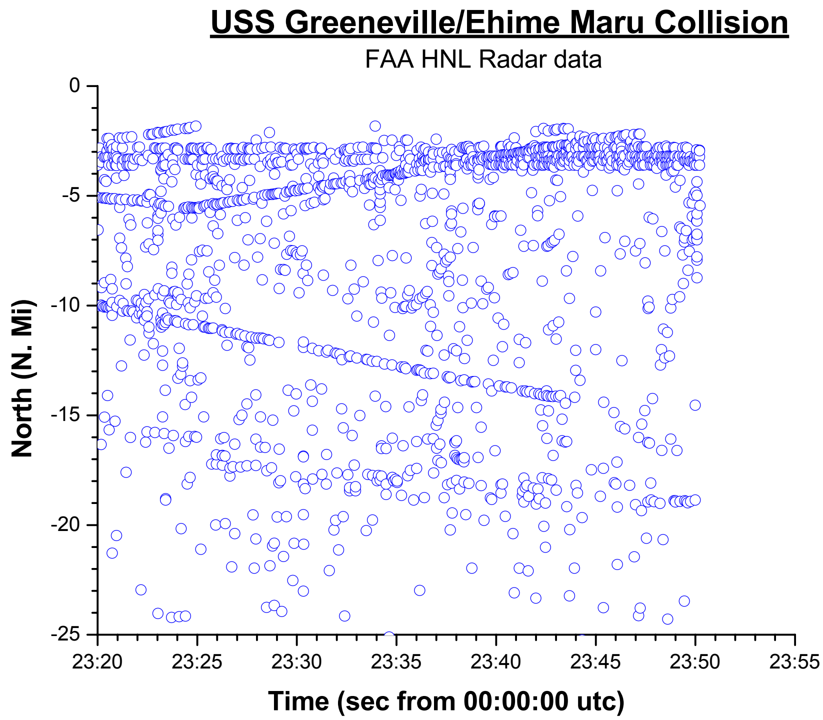


Figure 1:North radar positions vs. time

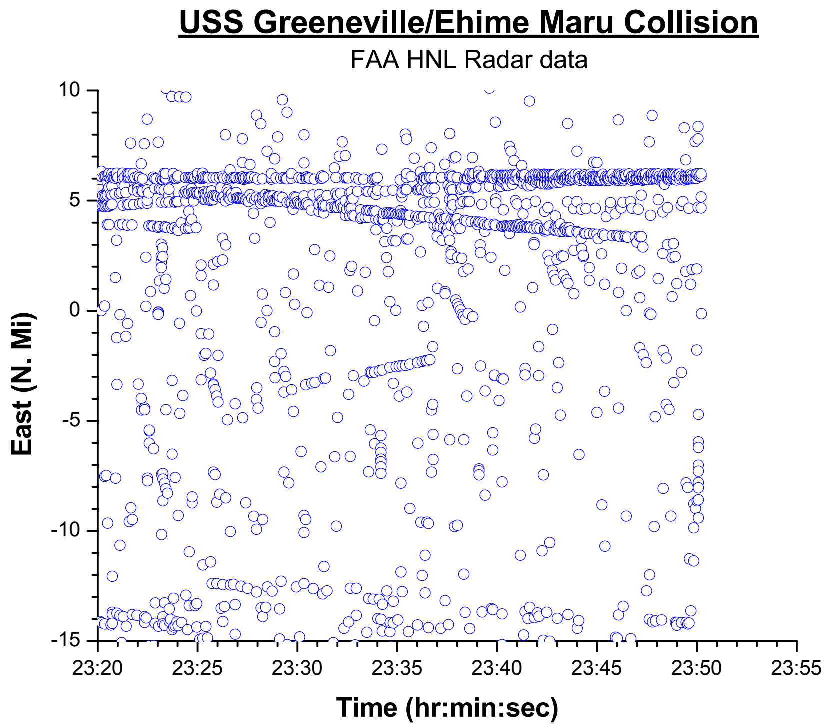


Figure 2: East radar positions vs. time

The radar tracks (radar returns sequential in time) in the above plots were separated out using the tracks program for comparison with sonar data. The resulting tracks are plotted with a map overlay in figure 3. Note that one track, identified as radar track 9, ends at the wreckage site. This track also ends at the 23:43 UTC collision time (as seen in "own-ship" data documented later in this report). Accordingly radar track 9 will be considered to be the Ehime Maru for the rest of this report. The track shows the Ehime Maru moving at 11 Kts on a heading of 166 deg.

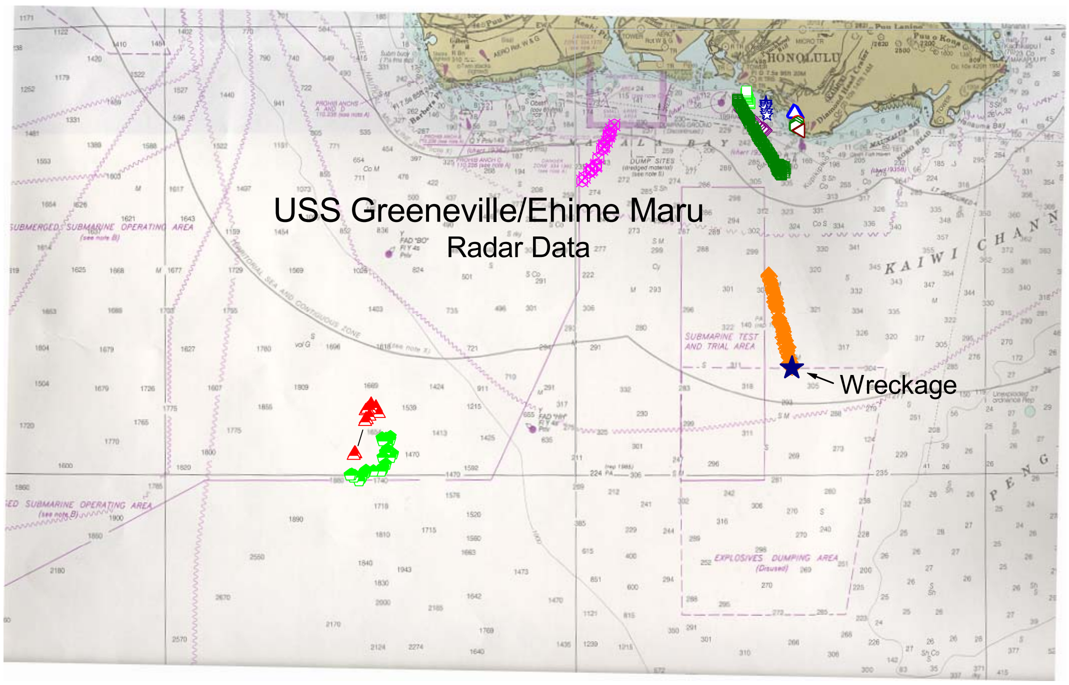


Figure 3: Radar tracks

USS Greeneville Track

The USS Greeneville was equipped with a Sonar Data Logger (SLOGGER) which records sonar, fire control (the control room station that develops target motion analysis (TMA)) and "own ship" motion.

A dat tape drive is located in the SIU (sonar interface unit) cabinet to record data from the SLOGGER Oracle database. The tape consists of TARed (a UNIX compression standard) ASCII data. Normally a tape is made at midnight.

The Navy provided the NTSB with the dat tape from the Greeneville covering the time of the collision. The data was uncompressed on a UNIX workstation temporarily disconnected from the network, transferred to a PC and burned onto a CD ROM. The files consisted of

Data for the Greeneville's motion (own ship data)
Towed Array parameters
Sonar and Fire Control data parameters

Since the towed array was not deployed, the towed array parameter file consisted of columns of zeros.

The recorded own ship parameters consisted of time, heading, pitch, roll, depth and speed. The angular data was obtained from the ESGN (an electrostatic gyro inertial navigation system). All own ship data was recorded once a second. There were a few points in the own-ship dataset where a second of recording was missed. Similarly, there were a few points in the data where recording time sequence was offset for a brief time (this usually accompanied a data drop). Noting that the speed and direction of a submarine cannot change much in one second, these bad data points were repaired manually.

The USS Greenville collided with the Ehime Maru as it surfaced after an "emergency blow" demonstration. Prior to this maneuver, the Greeneville ascended to periscope depth to verify that the area was clear. Figure 4 shows keel depth and heading for a time interval that covers the ascent to periscope depth, the dive and the emergency blow to the collision. The keel depth data holds 90.84 ft for 7 seconds just prior to the collision. The Safety Board worked with the Navy to determine the cause of this false reading but nothing conclusive was determined.

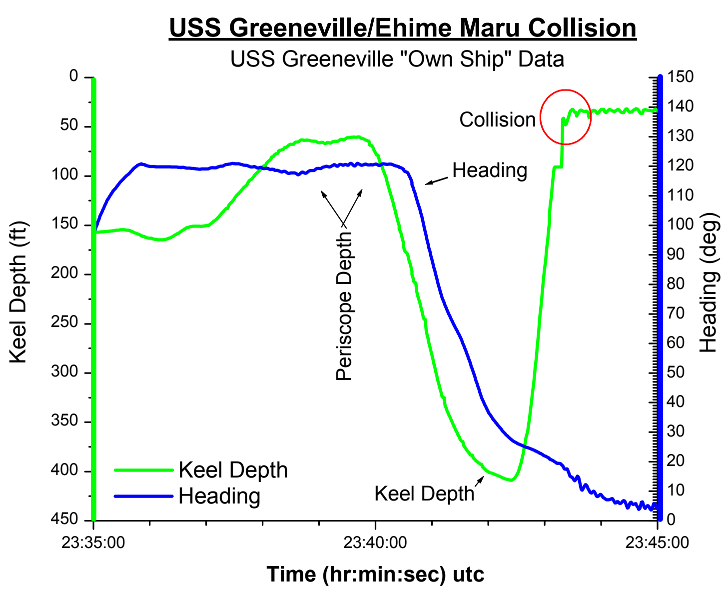


Figure 4: USS Greeneville Keel Depth and Heading

The USS Greeneville's pitch and roll angle are plotted in figures 5 and 6 respectively for the same time period shown in figure 4. The roll angle trace in particular shows the collision at approximately 23:43:20 UTC.

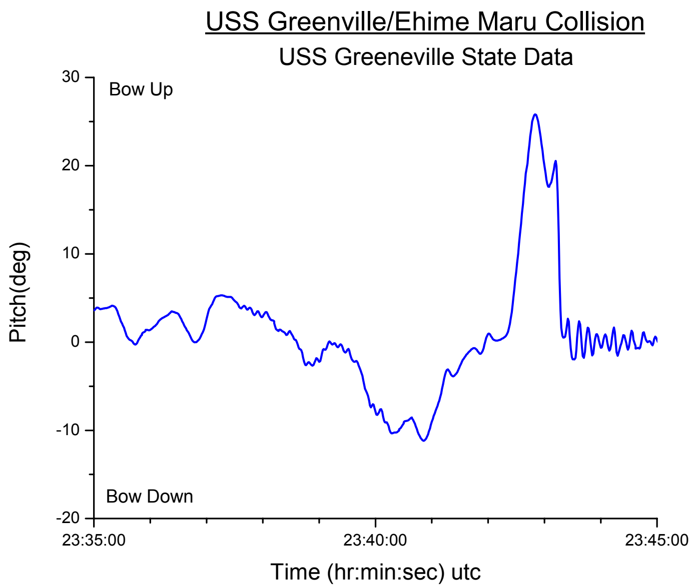


Figure 5: Greeneville Pitch Attitude

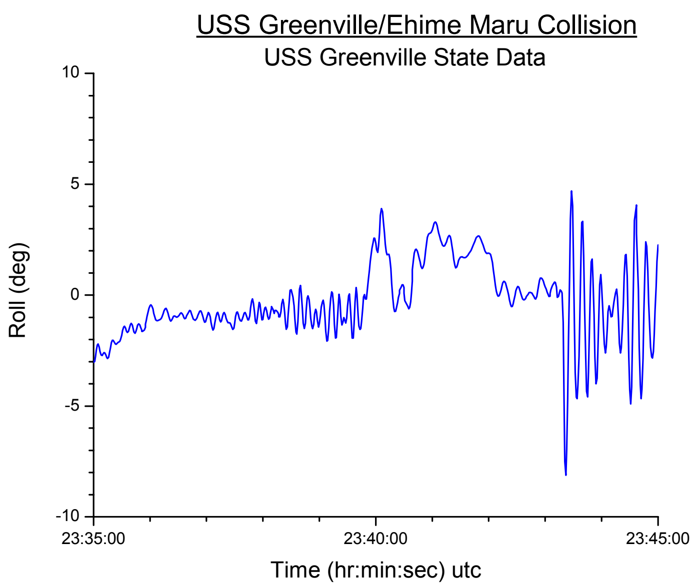


Figure 6: USS Greeneville Roll Attitude

The Greeneville's position was not recorded. However, the Greeneville's relative position to a point at a given time could be calculated from the recorded data. The Greeneville's position at the time of the collision was determined from the Ehime Maru's track and, since the clock offset between Honolulu radar and the Greeneville's

SLOGGER clock was not known precisely, the post collision sonar bearings to the Ehime Maru was used to refine the collision position. This corresponded to a 120 sec shift forward in time for the radar data to synchronize with the Greeneville's SLOGGER clock. The recorded speed along the boats long axis was first converted into velocity components.

V_{East} = Speed cos(pitch)sin(heading).
V_{North} = Speed cos(pitch)cos(heading).
V_{up} = Speed sin(pitch).

These component velocities were then integrated forward or backward from the collision point to obtain the track of the Greeneville. The track of the Greenville and the track of the Ehime Maru are shown together in map view in figure 7. Figure 8 shows a 3 dimensional representation of the Greeneville and Ehime Maru track from the ascent to periscope depth to the diving left turn and to the collision with the Ehime Maru and back to the wreckage site. Note that depth is not to scale with East and North position.

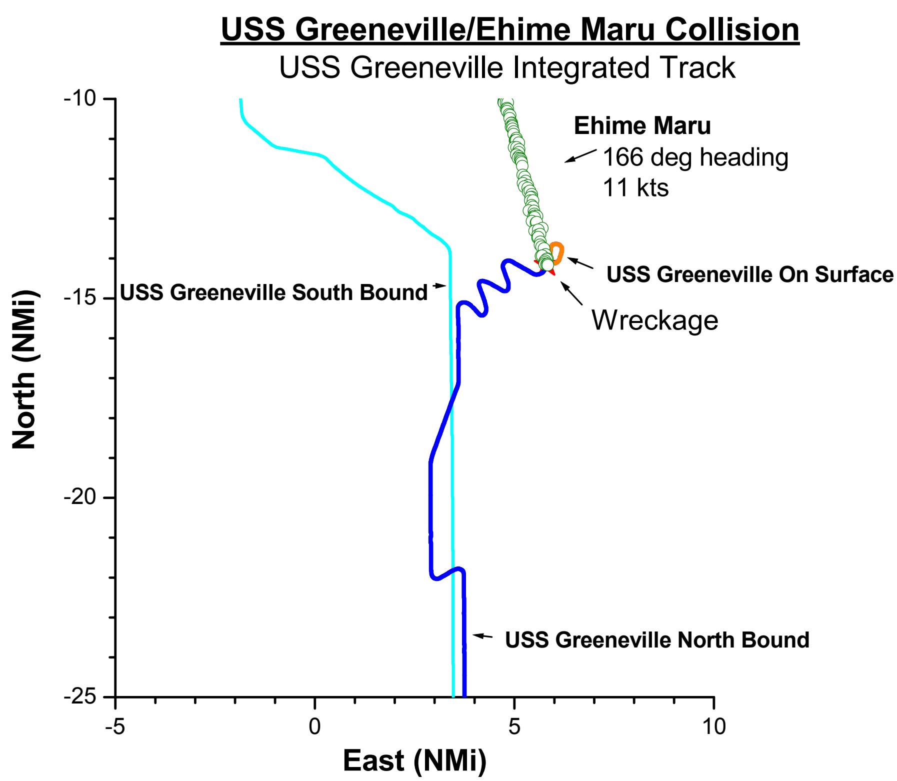


Figure 7: USS Greeneville/Ehime Maru tracks

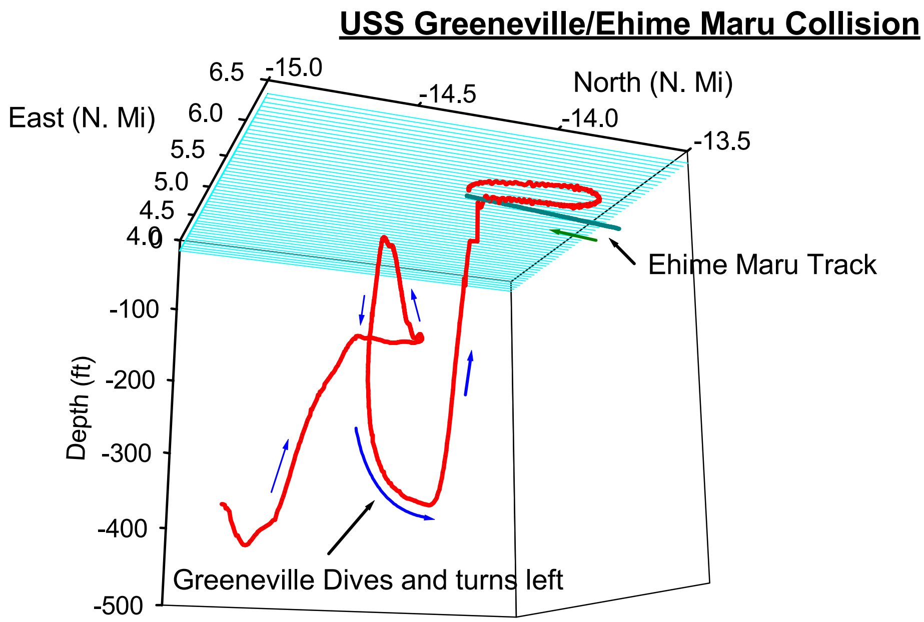


Figure 8: 3D track

Recorded Sonar and Fire Control data

During the collision voyage, the USS Greeneville was using passive sonar to determine the direction to other vessels by listening to noise from the other vessels (targets). This is in contrast to active sonar in which the Greeneville could have sent out a sound (a ping) and then listened for the reflection off other vessels. The Navy reports that submarines do not generally use active sonar because:

1) Active sonar's performance is highly dependent on the environment and may not yield an accurate picture of the ship's surrounding.
2) Passive sonar provides continuous data on contacts at significantly greater ranges than active sonar.
3) Active sonar reveals a ship's position which is contrary to most missions a submarine conducts in the real world and which they must train for in local operating areas.

Sonar provides bearing to acquired targets to Fire Control. Fire Control is responsible for calculating a solution for the target. The target solution consists of the range and bearing to the target, it's course and its speed. These solution parameters are estimated from the time history of the target bearing and the time history of the own-ship heading.

When a target is first acquired, the Fire control computer automatically provides a Kalman Automated Sequential Track (KAST) solution that is initially entered into the database as the system solution. Subsequent to this, the Fire Control Technician calculates a solution for the acquired target and, once he enters the solution as the system solution, the fire control technician produces all subsequent solutions for a given target. The SLOGGER records the system solution. Thus the first target solution recorded by the SLOGGER for a given target is automatic from the KAST system while subsequent solutions are derived from Fire Control Technician input. The system will update the solution range as time moves forward based on the course and speed entered by the Fire Control Technician. The resolution on this recorded range is 1 K yard. Note that only solutions that the Fire Control Technician enters into the system as the system solutions (and subsequent automatic system range updates) are recorded. Neither the interim solutions the Fire Control Technician may develop nor the mode used on his console are recorded.

Targets are assigned numbers in the order that they are encountered on the voyage. The first sonar target is Sierra 1, the second Sierra 2 and so forth. Sierra 12, 13 and 14 were being tracked at the time of the collision. Though not being tracked at the time of the collision, the sonar contacts Sierra 10 and Sierra 11 were also studied. The timing of these sonar contacts is shown in figure 9.

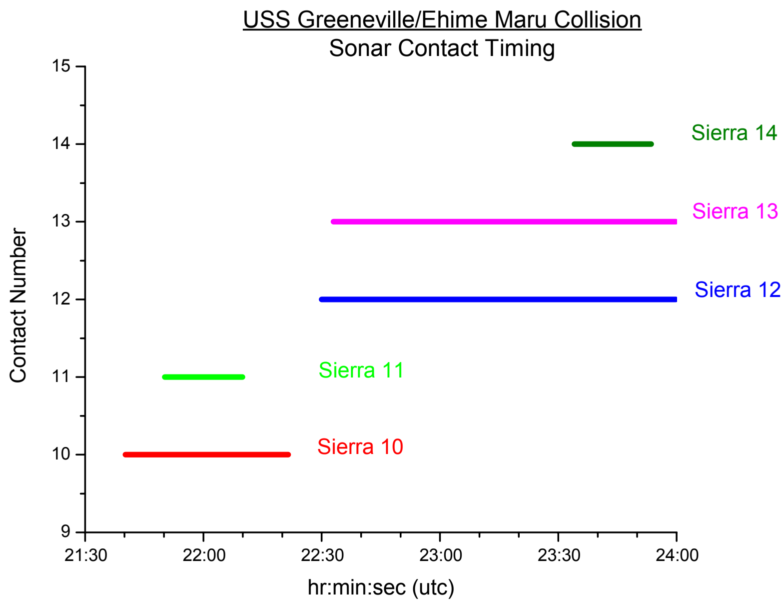
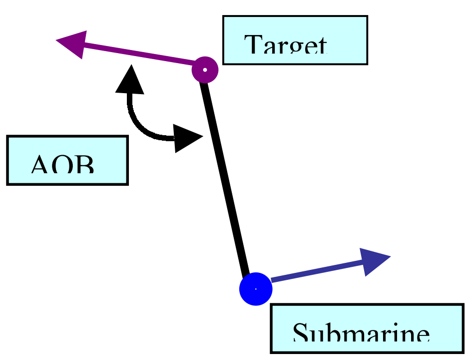


Figure 9: Sonar Contact timing

The recorded sonar and fire control data for Sierra 10 through 14 are presented on the following pages. One recorded parameter is Angle On the Bow (AOB). Angle On the Bow is the aspect that the target vessel is presenting to the tracking vessel.



Sonar/Radar Correlation

The true bearing to the radar targets shown in figure 3 was calculated from the radar position and the own-ship integrated position. These calculated true bearing time histories were compared to the bearing time history recorded for Sierra 12, 13 and 14. The bearing time history for Sierra 12 did not correlate with any bearing to the radar time history identified. Consistent with previous identification, the bearing time history for Sierra 13 correlated with radar track 9. The bearing time history for Sierra 14 correlated with radar track 7. The Sierra 10 and 11 sonar contacts occurred before the radar data and could not be correlated. The radar tracks corresponding to the Sierra 13 and 14 sonar contacts are so labeled in figure 10.

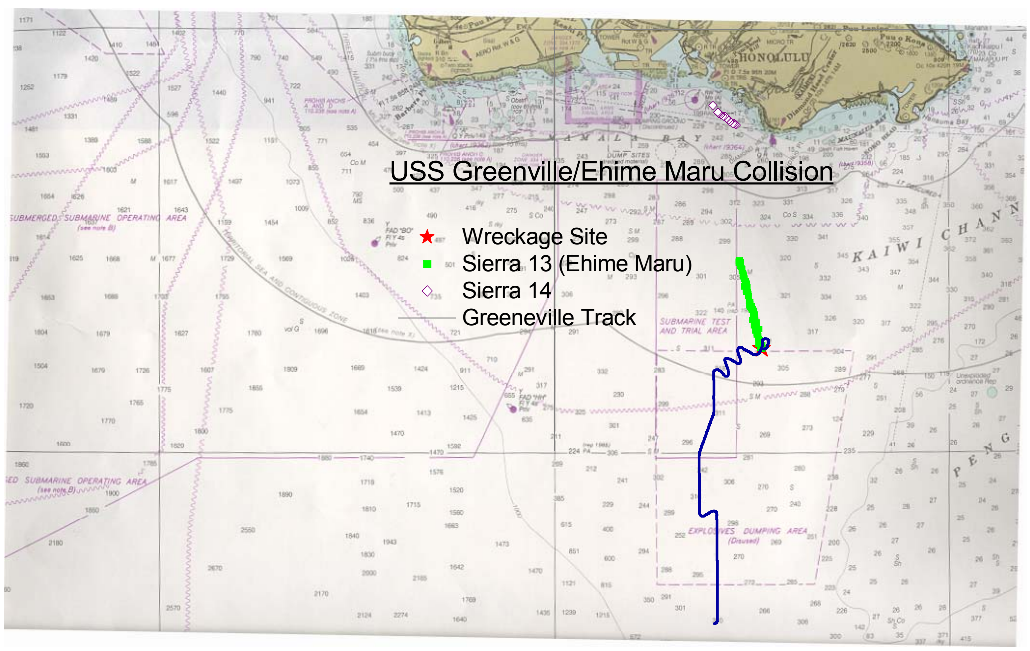


Figure 10: Correlated Radar Returns

Sierra 10 Contact

Data recorded from sonar for Sierra 10 are plotted in figures 11 and 12. A plot of signal to noise ratio is presented in figure 11. The Doppler opening or closing flag for sonar is plotted in figure 12. This Doppler flag defaults to data from fire control unless manually entered by the sonar operator. Sonar bearing is plotted together with fire control bearing in figure 20.

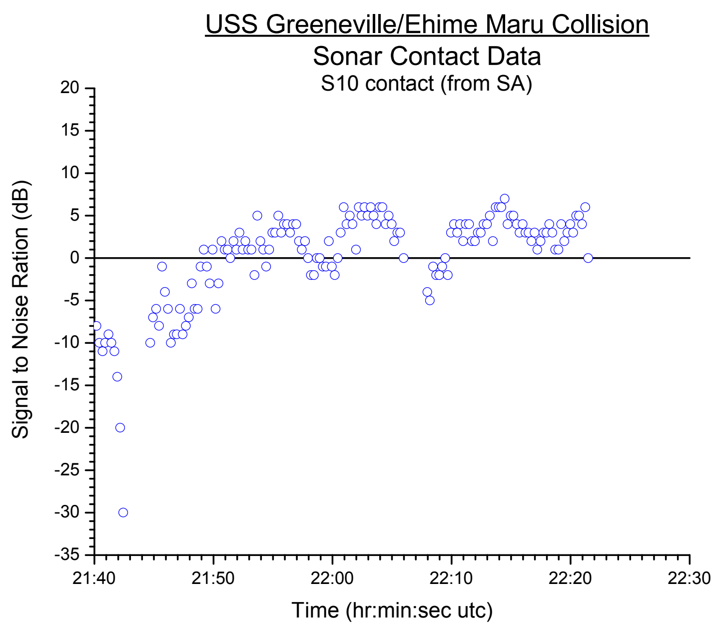


Figure 11: S10 Signal to Noise Ratio

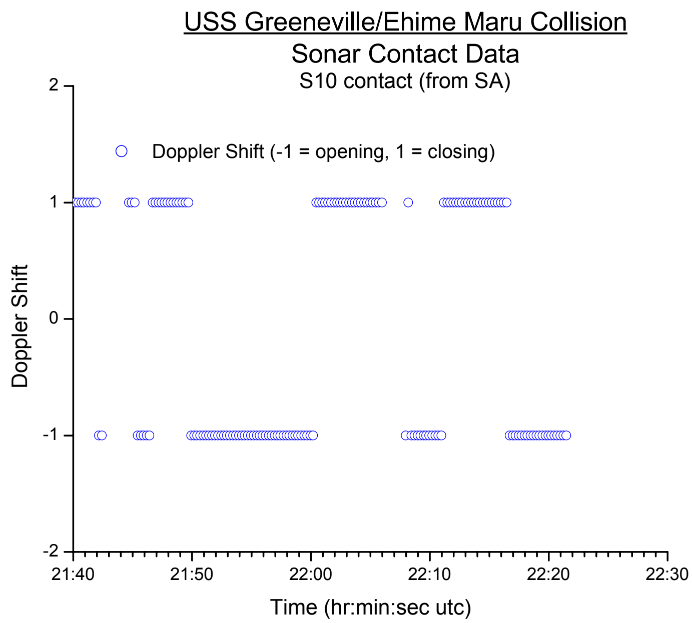


Figure 12: S10 Doppler Shift

The following data from sonar remained constant from the initial contact with the Sierra 10 target until the contact was lost. Note that DE defaults to zero. Thus the zero recorded value is an indication that the recorded DE is not valid. Also, TQI (Track Quality Indicator) defaults to “strong.” The “strong” TQI is not an indication of track quality.

PARAMETER	VALUE	MEANING
lsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	1	Automatically logged
Processor	D	DIMUS
TrkString	C*	BSY – 1 Sphere PBB
lsBRG	1	Automatically logged
lsMovement	1	Automatically logged
MovementCode	M	Constant Brg rate
lsDE	1	Automatically logged
DE	0	Tracker’s DE position
lsSNR	1	Automatically logged
TQI	S	Strong

Parameters from the recorded system fire control solution for the Sierra 10 target are plotted in figures 13 to 19. Fire control solution bearing is included in the bearing comparison in figure 20.

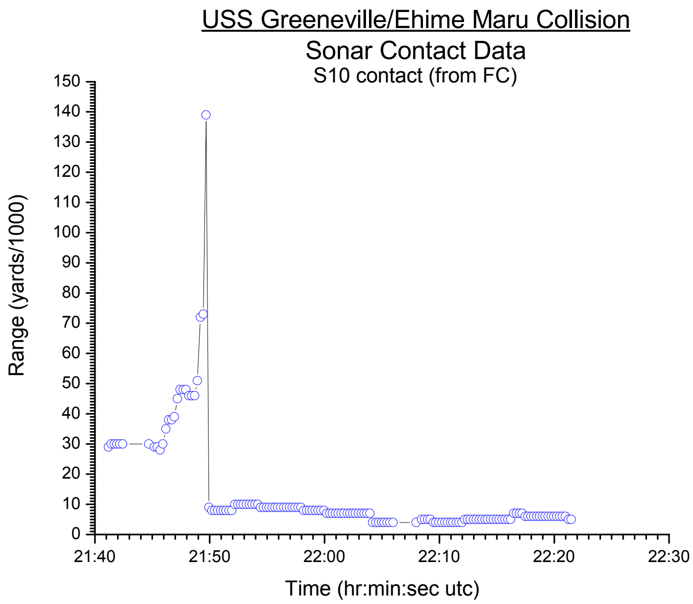


Figure 13: S10 FC Range Solution

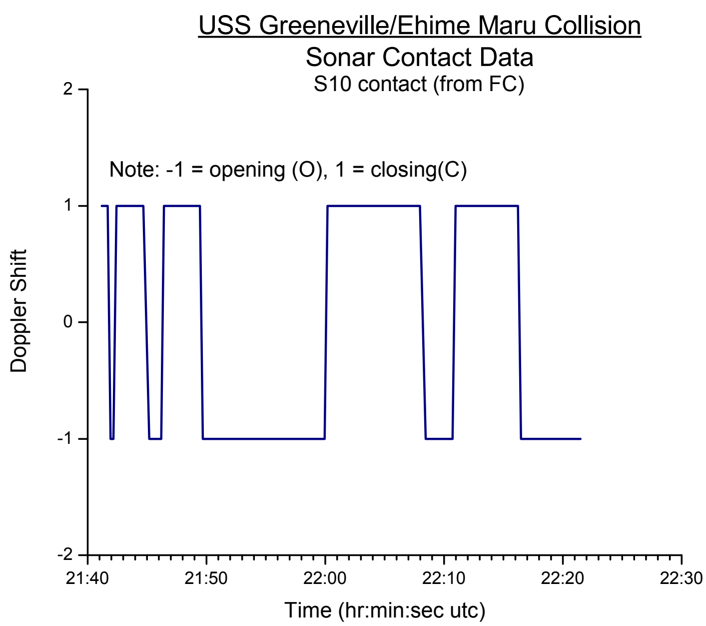


Figure 14: S10 FC Doppler shift

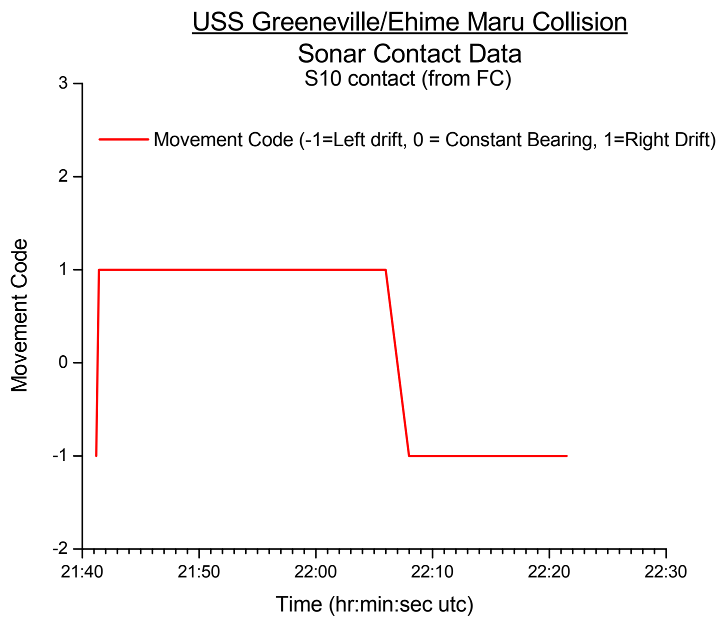


Figure 15: S10 FC movement code

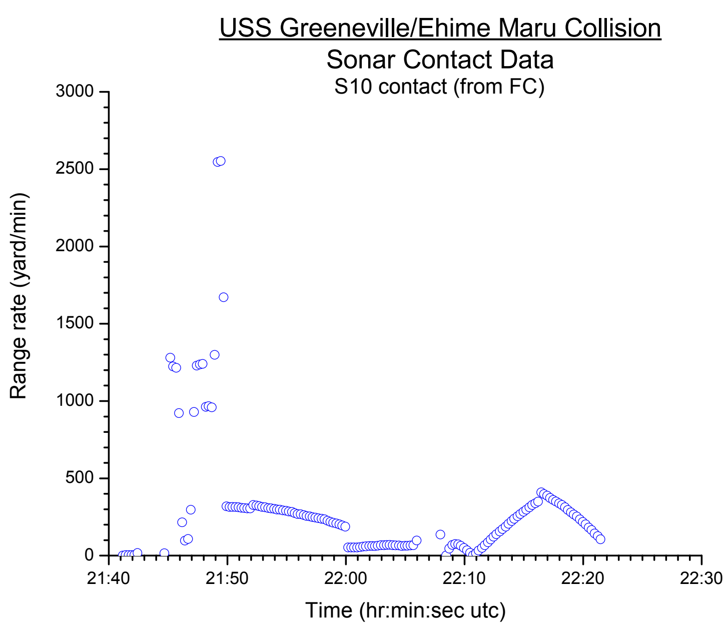


Figure 16: S10 FC range rate

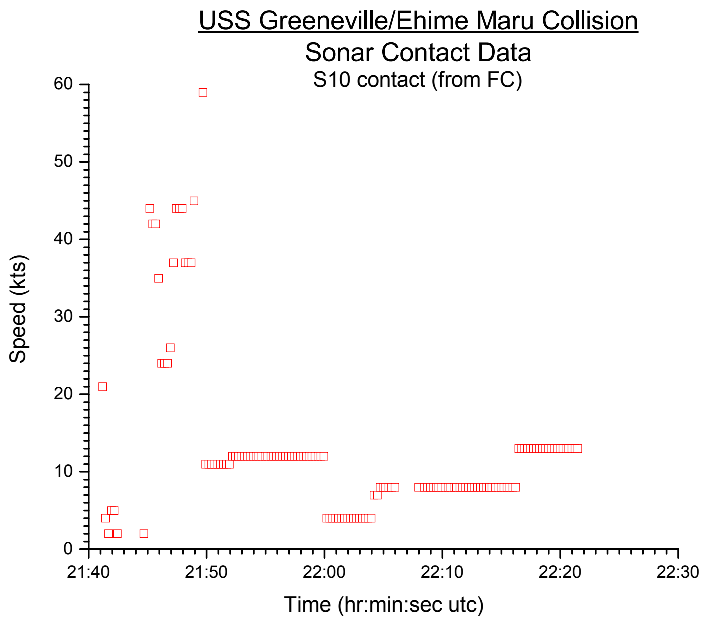


Figure 17: S10 FC speed solution

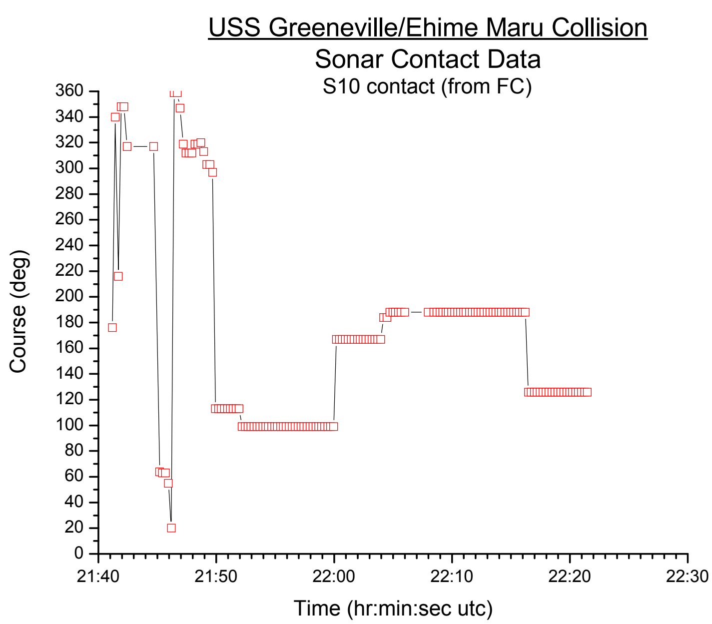


Figure 18: S10 FC course solution

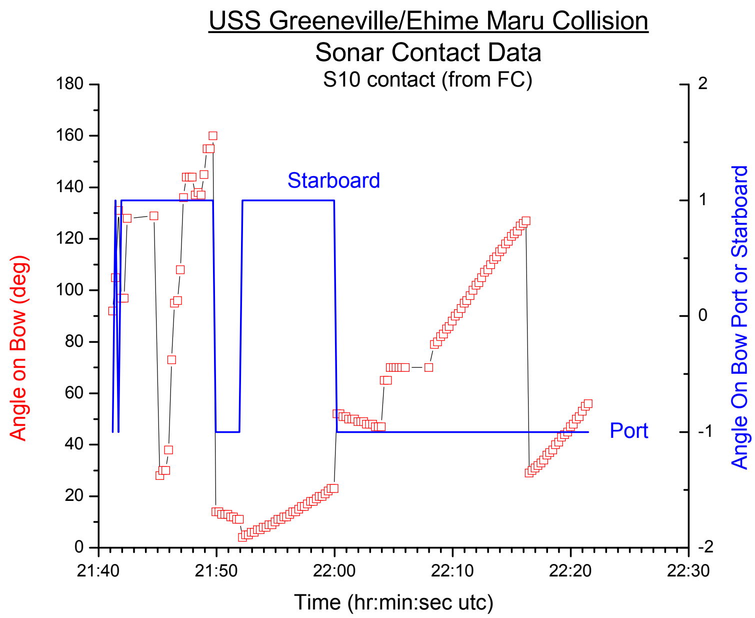


Figure 19: S10 FC angle on bow solution

The following fire control parameters were unchanged from the initial contact with the Sierra 10 target till the contact was lost. Note that the Port/Starboard flag is invalid for spherical array contacts such as this.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	0	Not used
TrkString	FCS	
LsBRG	1	Automatically logged
PortSTRBDflag	P	Port (not valid)
lsMovement	1	Automatically logged
LsDE	0	Not used
LsSNR	0	Not used
lsSolutionSourse	0	Not used
LsRange	1	Automatically logged
LsCourse	1	Automatically logged
LsSpeed	1	Automatically logged
LsAOB	1	Automatically logged
lsRangerate	1	Automatically logged

Relative bearing recorded from sonar and true bearing recorded from the fire control system solution are presented in figure 20. A calculated true bearing developed from own-ship heading and sonar bearing is also presented. Note that calculated true bearing is invalid in the time periods that sonar bearing is not available.

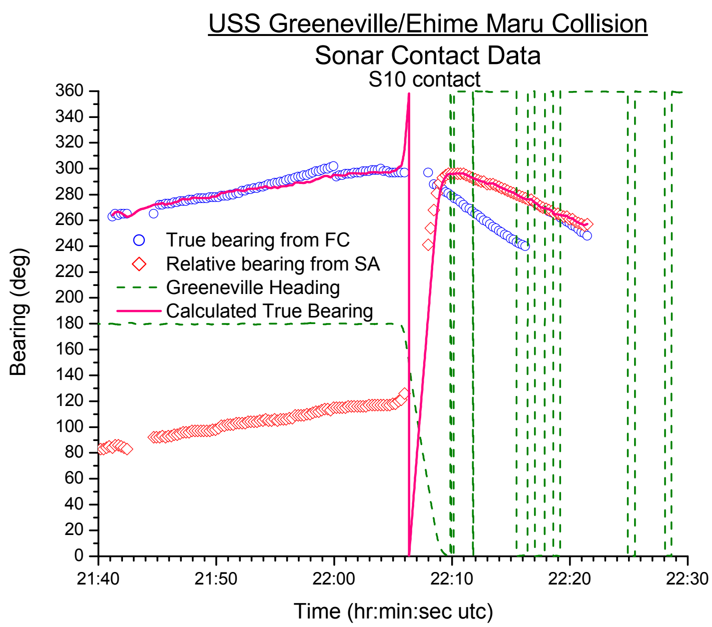


Figure 20: S10 bearing comparison

Sierra 11 Contact

Data recorded from sonar for Sierra 11 are plotted in figures 21 and 22. A plot of signal to noise ratio is presented in figure 21. The Doppler opening or closing flag for sonar is plotted in figure 22. This Doppler flag defaults to data from fire control unless manually entered by the sonar operator. Sonar bearing is plotted together with fire control bearing in figure 31.

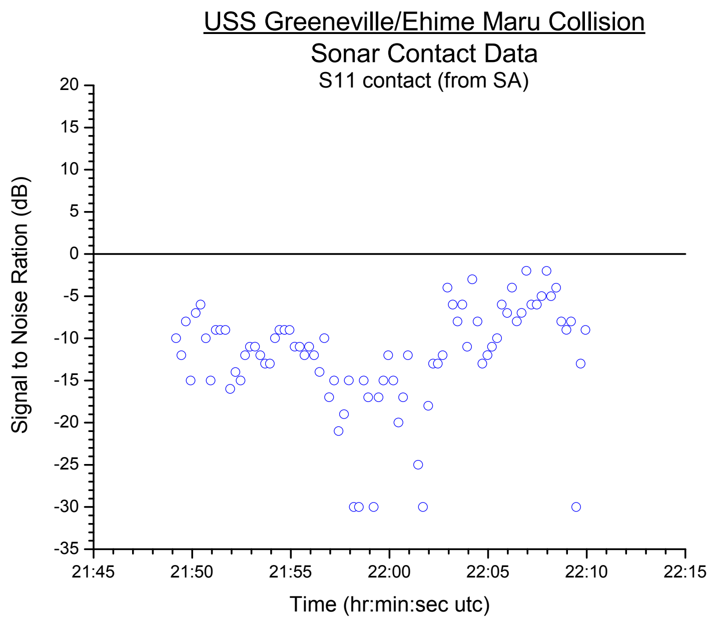


Figure 21: S11 signal to noise ratio

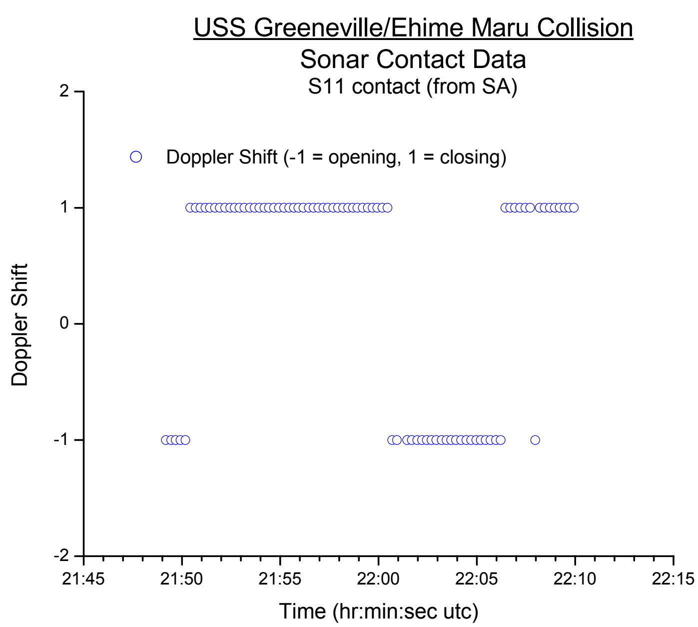


Figure 22: S11 Doppler shift

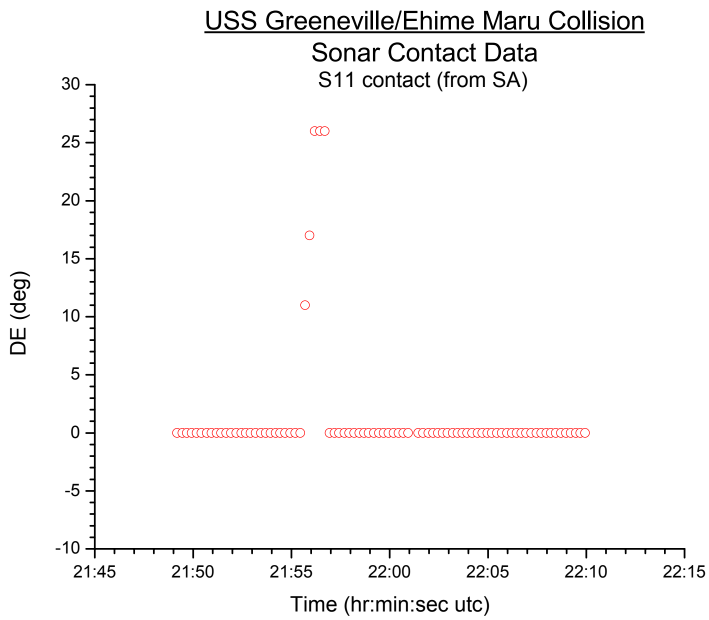


Figure 23: S11 DE

Note that DE defaults to zero. Thus the zero recorded value is an indication that the recorded DE is not valid.

The following parameters were unchanged from the initial contact with the Sierra 11 target till the contact was lost. Note that TQI (Track Quality Indicator) defaults to "strong." The "strong" TQI is not an indication of track quality.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
LsSensor	1	Automatically logged
LsProcessor	1	Automatically logged
Processor	D	DIMUS
TrkString	D*	BSY – 1 Sphere PBB
LsBRG	1	Automatically logged
lsMovement	1	Automatically logged
MovementCode	M	Constant Brg rate
lsDE	1	Automatically logged
lsSNR	1	Automatically logged
TQI	S	Strong

Parameters from the recorded system fire control solution for the Sierra 11 target are plotted in figures 24 to 30. Fire control solution bearing is included in the bearing comparison in figure 31.

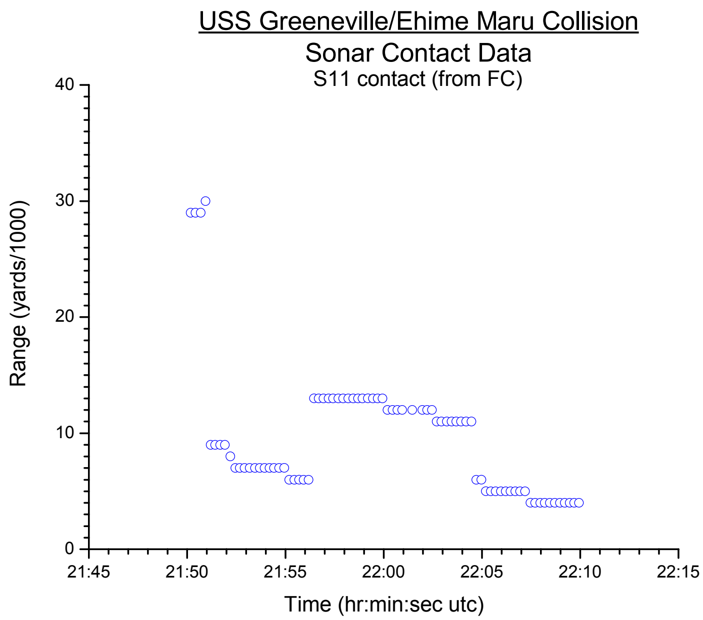


Figure 24: S11 FC range solution

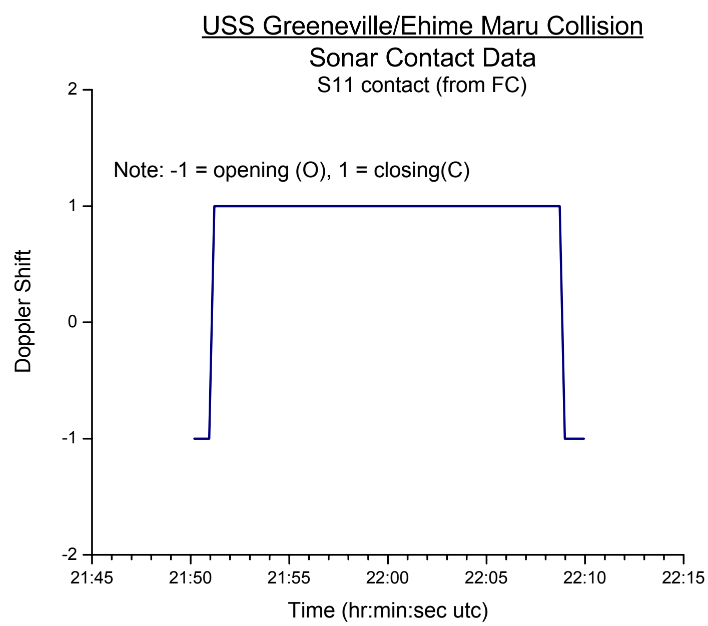


Figure 25: S11 FC Doppler shift

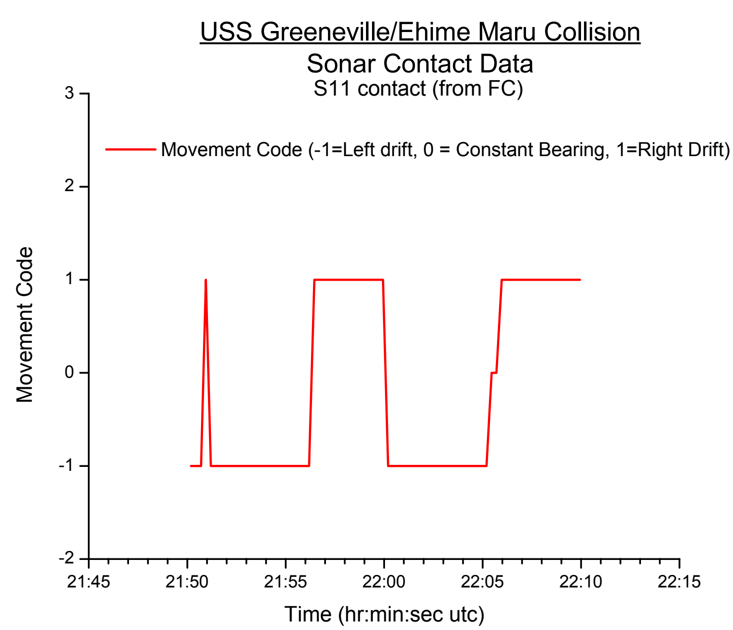


Figure 26: S11 Movement Code

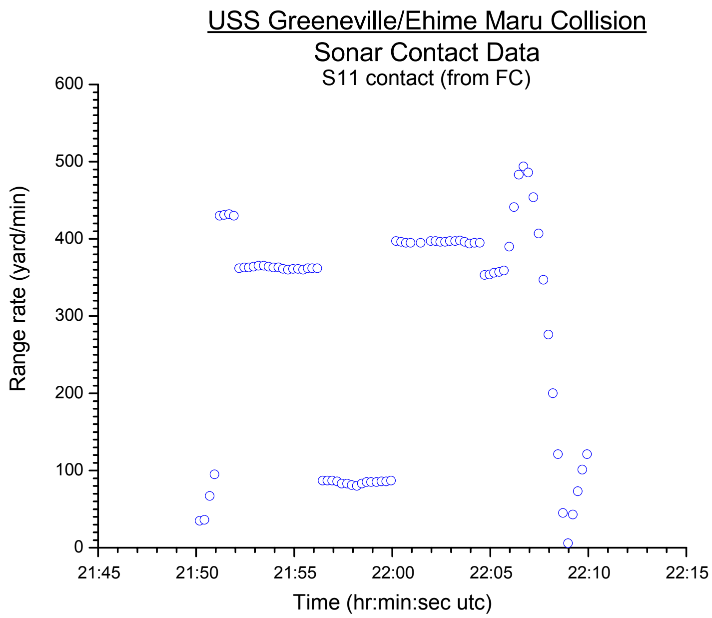


Figure 27: S11 FC range rate

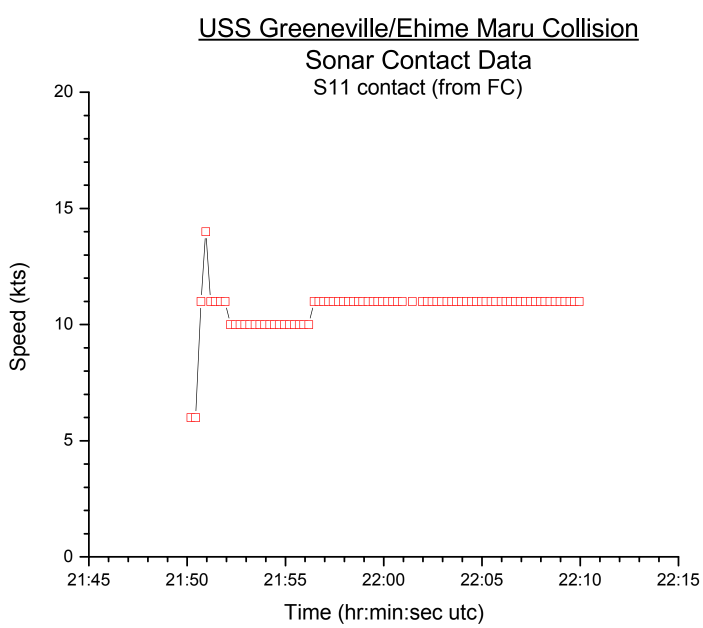


Figure 28: S11 FC speed solution

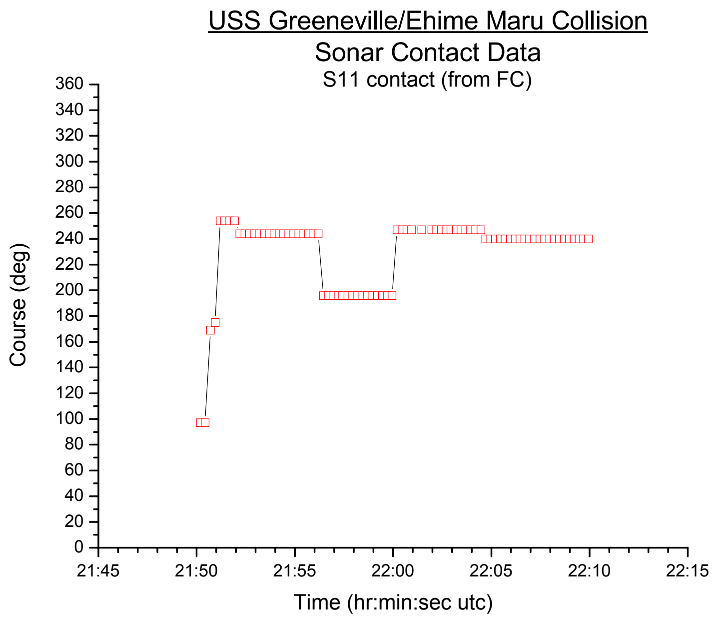


Figure 29: S11 FC course solution

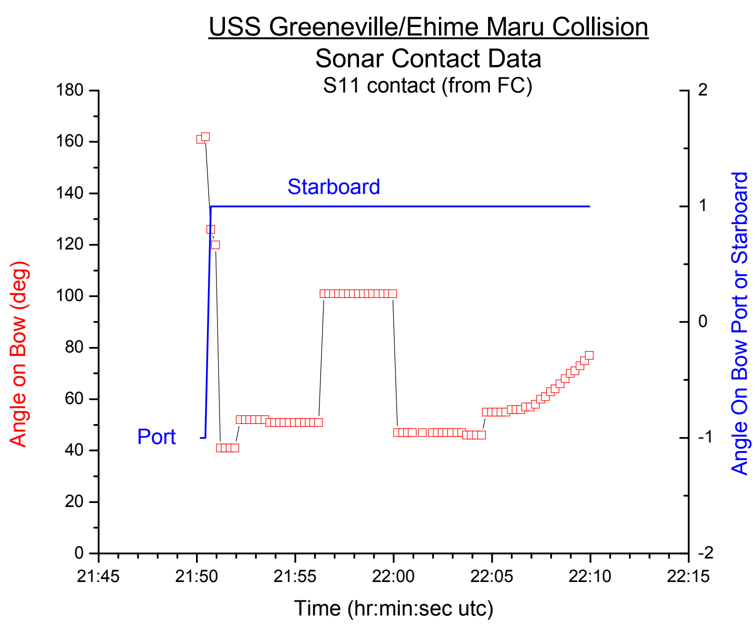


Figure 30: S11 Angle on Bow

The following fire control parameters were unchanged from the initial contact with the Sierra 11 target till the contact was lost. Note that the Port/Starboard flag is invalid for spherical array contacts such as this.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	0	Not used
TrkString	FCS	
lsBRG	1	Automatically logged
PortSTRBDflag	P	Port (invalid)
lsMovement	1	Automatically logged
lsDE	1	Automatically logged
lsSNR	0	Not used
lsSolutionSourse	0	Not used
lsRange	1	Automatically logged
lsCourse	1	Automatically logged
lsSpeed	1	Automatically logged
lsAOB	1	Automatically logged
lsRangerate	1	Automatically logged

Relative bearing recorded from sonar and true bearing recorded from the fire control system solution are presented in figure 31. A calculated true bearing developed from own-ship heading and sonar bearing is also presented.

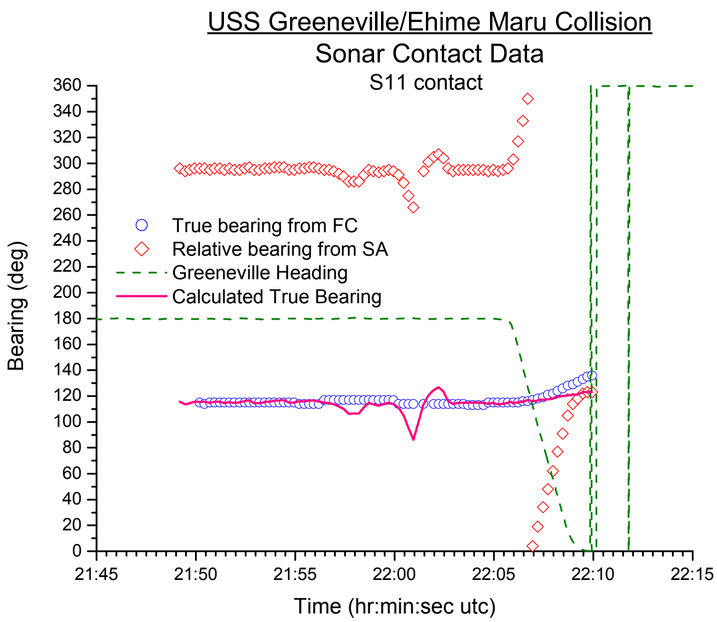


Figure 31: S11 bearing comparison

Sierra 12 Contact

Data recorded from sonar for Sierra 12 are plotted in figures 32 and 33. A plot of signal to noise ratio is presented in figure 32. The Doppler opening or closing flag for sonar is plotted in figure 33. This Doppler flag defaults to data from fire control unless manually entered by the sonar operator. Sonar bearing is plotted together with fire control bearing in figure 41.

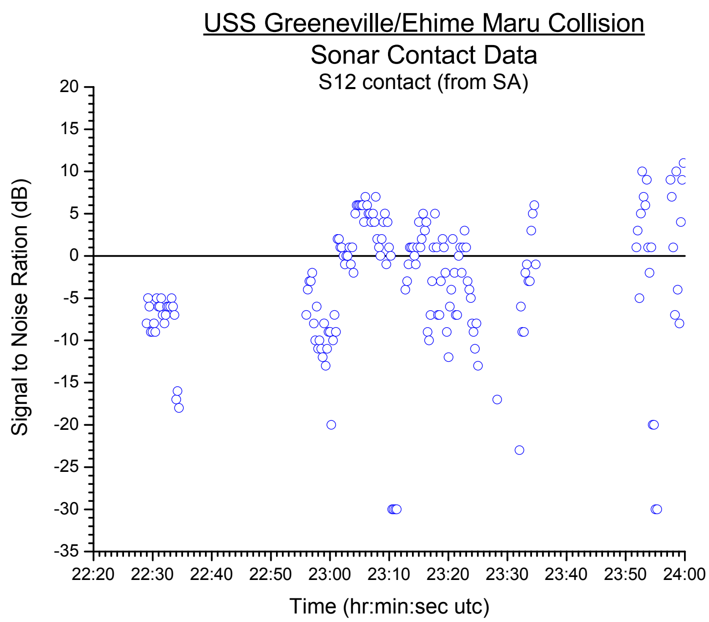


Figure 32: S12 signal to noise ratio

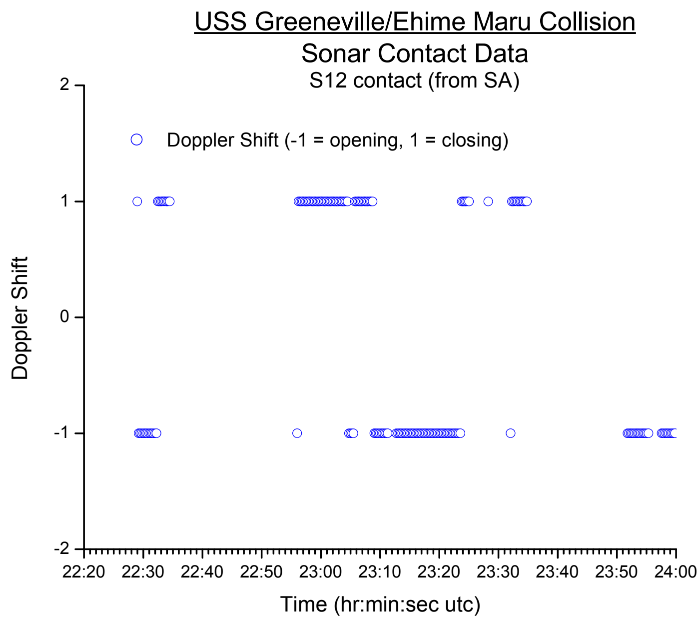


Figure 33: S12 sonar Doppler shift

The following data from sonar remained constant from the initial contact with the Sierra 12 target till the contact was lost. Note that DE defaults to zero. Thus the zero recorded value is an indication that the recorded DE is not valid. Also, TQI (Track Quality Indicator) defaults to "strong." The "strong" TQI is not an indication of track quality.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
LsSensor	1	Automatically logged
LsProcessor	1	Automatically logged
Processor	D	DIMUS
TrkString	D* to C* at 22:56	BSY – 1 Sphere PBB
LsBRG	1	Automatically logged
lsMovement	1	Automatically logged
MovementCode	M	Constant Brg rate
lsDE	1	Automatically logged
DE	0	Tracker's DE position
lsSNR	1	Automatically logged
TQI	S	Strong

Parameters from the recorded system fire control solution for the Sierra 12 target are plotted in figures 34 to 40. Fire control solution bearing is included in the bearing comparison in figure 41.

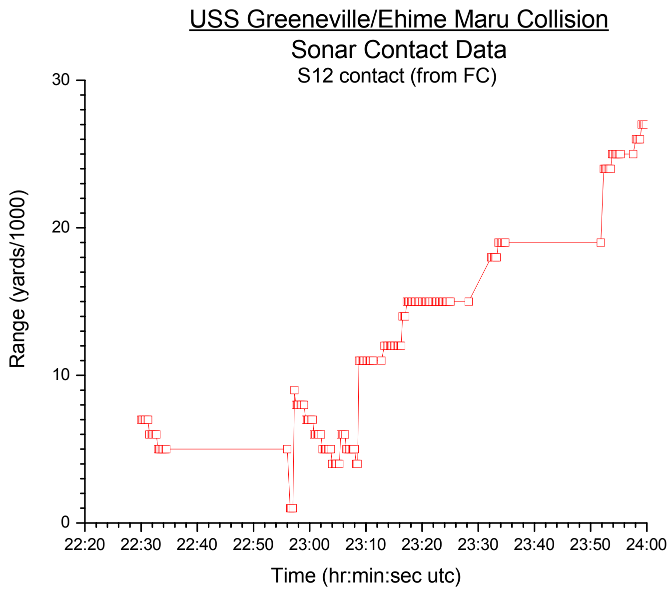


Figure 34: S12 FC range solution

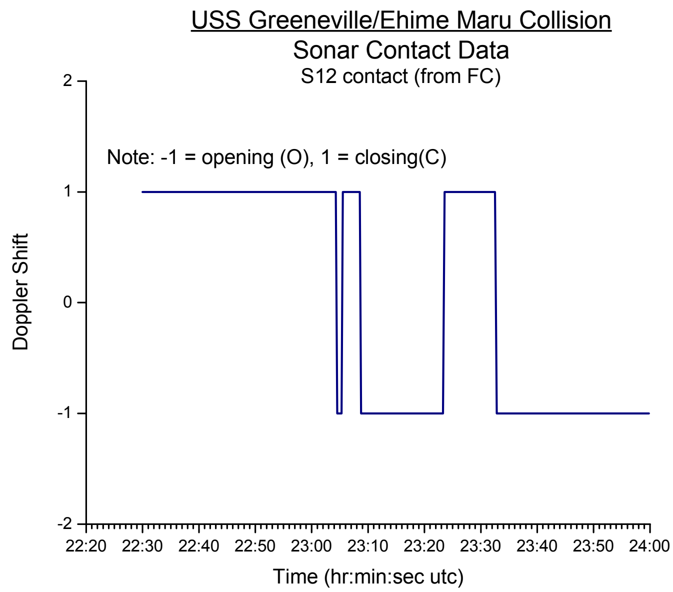


Figure 35: S12 FC Doppler shift

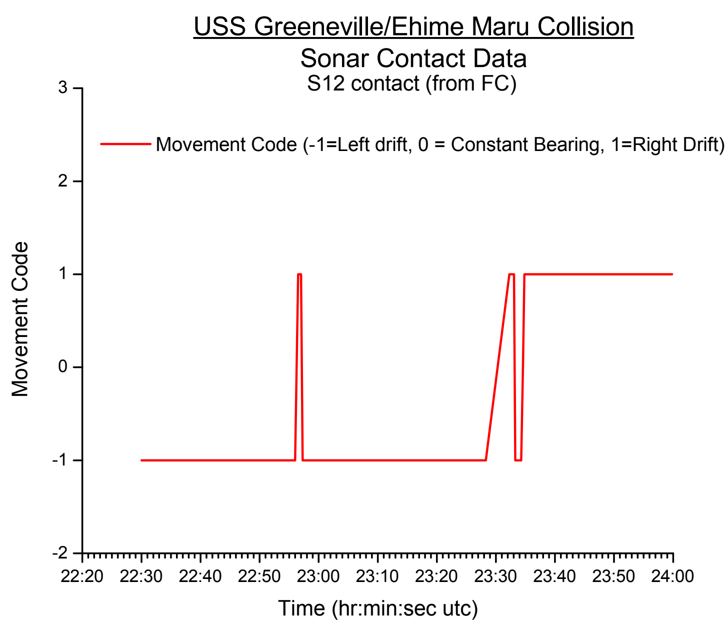


Figure 36: S12 Port/Starboard flag & Range Code

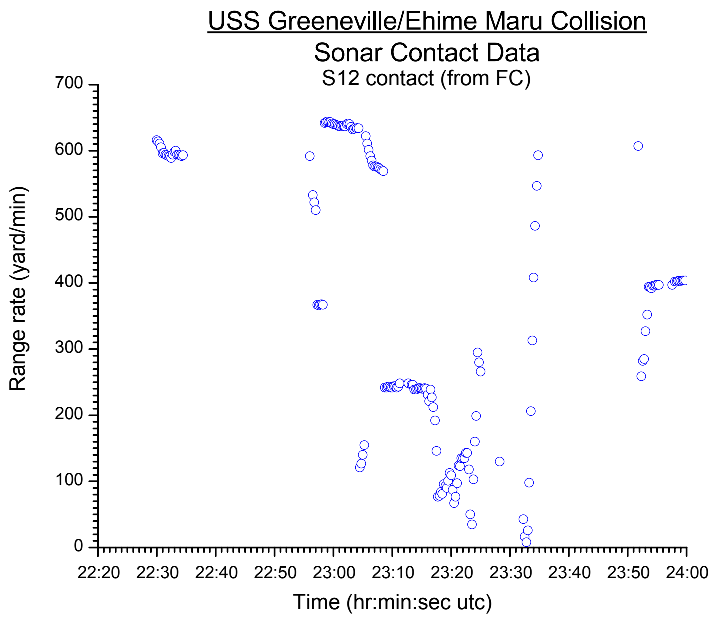


Figure 37: S12 FC Range rate

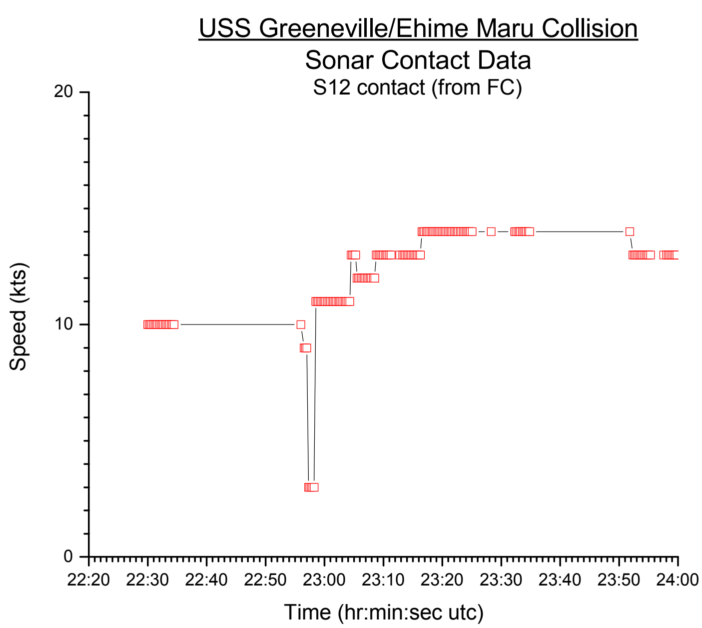


Figure 38: S12 FC solution speed

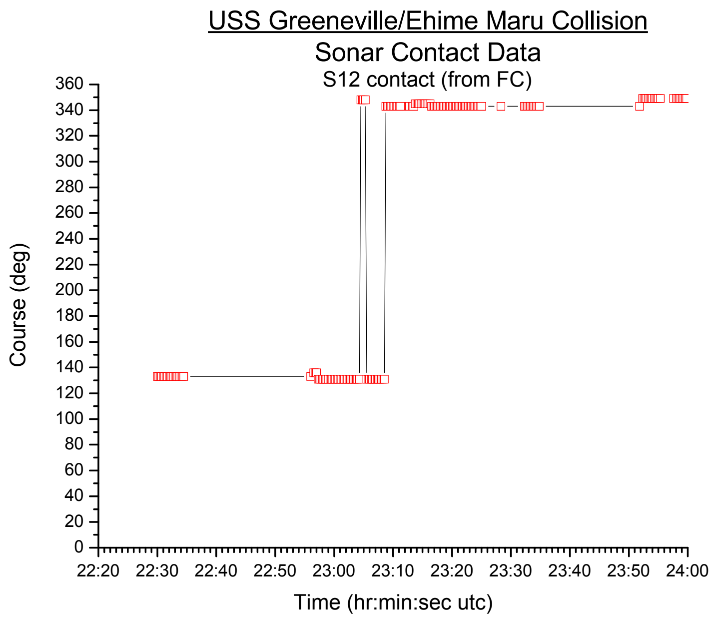


Figure 39: S12 FC course solution

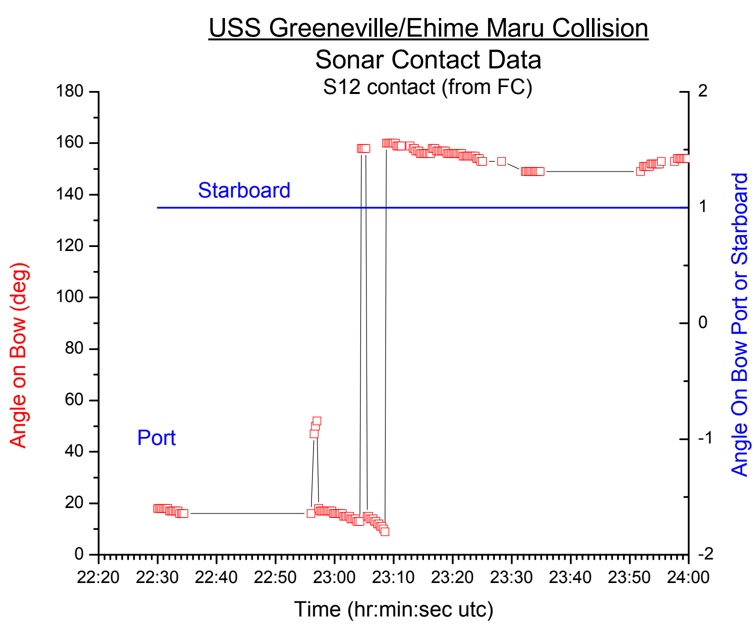


Figure 40: S12 Angle on Bow

The following fire control parameters were unchanged from the initial contact with the Sierra 12 target until the contact was lost. Note that the Port/Starboard flag is invalid for spherical array contacts such as this.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	0	Not used
TrkString	FCS	
lsBRG	1	Automatically logged
PortSTRBDflag	P	Port (invalid)
lsMovement	1	Automatically logged
lsDE	1	Automatically logged
lsSNR	0	Not used
lsSolutionSourse	0	Not used
lsRange	1	Automatically logged
lsCourse	1	Automatically logged
lsSpeed	1	Automatically logged
lsAOB	1	Automatically logged
lsRangerate	1	Automatically logged

Relative bearing recorded from sonar and true bearing recorded from the fire control system solution are presented in figure 41. A calculated true bearing developed from own-ship heading and sonar bearing is also presented. Note that calculated true bearing is invalid in the time periods that sonar bearing is not available.

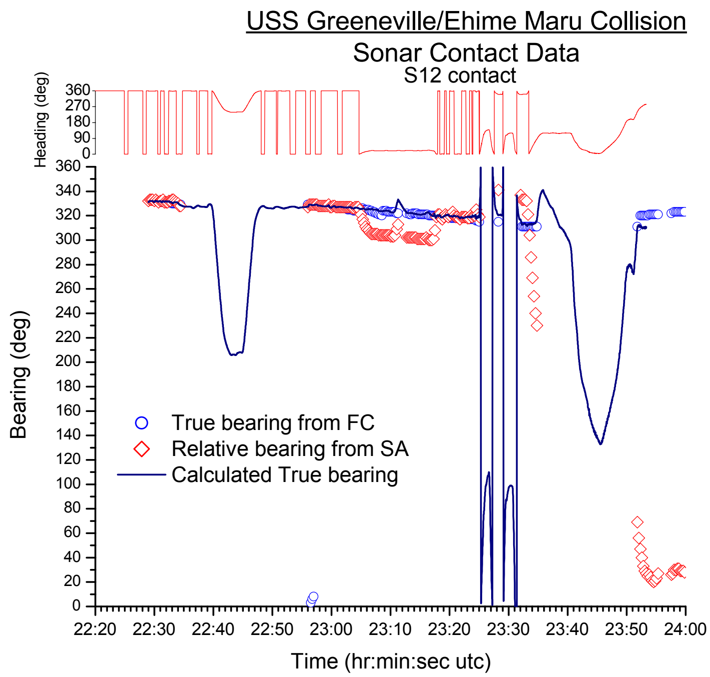


Figure 41: Bearing

Sierra 13 Contact

Data recorded from sonar for Sierra 13 are plotted in figures 42 and 43. A plot of signal to noise ratio is presented in figure 42. The Doppler opening or closing flag for sonar is plotted in figure 43. This Doppler flag defaults to data from fire control unless manually entered by the sonar operator. Sonar bearing is plotted together with fire control bearing in figure 50.

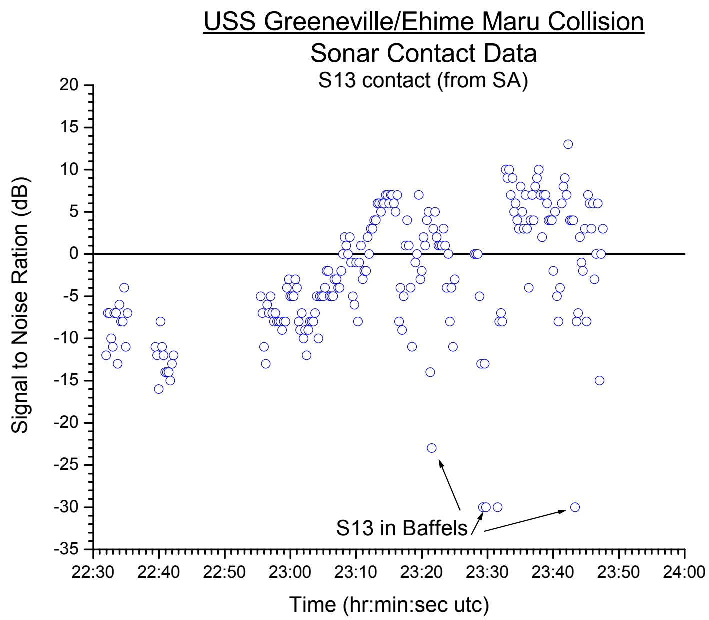


Figure 42: S13 Sonar signal to noise ratio

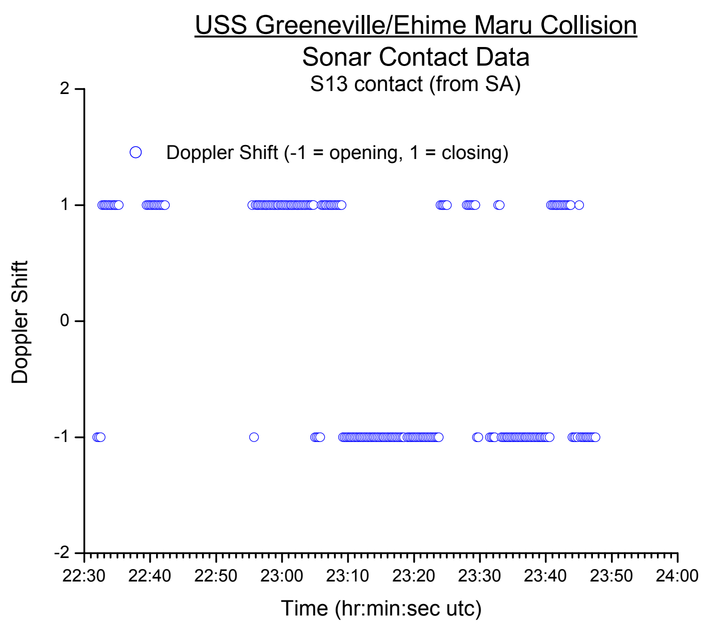


Figure 43: S13 sonar Doppler Shift

The following data from sonar remained constant from the initial contact with the Sierra 13 target till the contact was lost. Note that DE defaults to zero. Thus the zero recorded value is an indication that the recorded DE is not valid. Also, TQI (Track Quality Indicator) defaults to "strong." The "strong" TQI is not an indication of track quality.

PARAMETER	VALUE	MEANING
lsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	1	Automatically logged
Processor	D	DIMUS
TrkString	B*	BSY – 1 Sphere PBB
lsBRG	1	Automatically logged
lsMovement	1	Automatically logged
MovementCode	M	Constant Brg rate
lsDE	1	Automatically logged
DE	0	Tracker's DE position
lsSNR	1	Automatically logged
TQI	S	Strong

Parameters from the recorded system fire control solution for the Sierra 13 target are plotted in figures 44 to 49. Fire control solution bearing is included in the bearing comparison in figure 50.

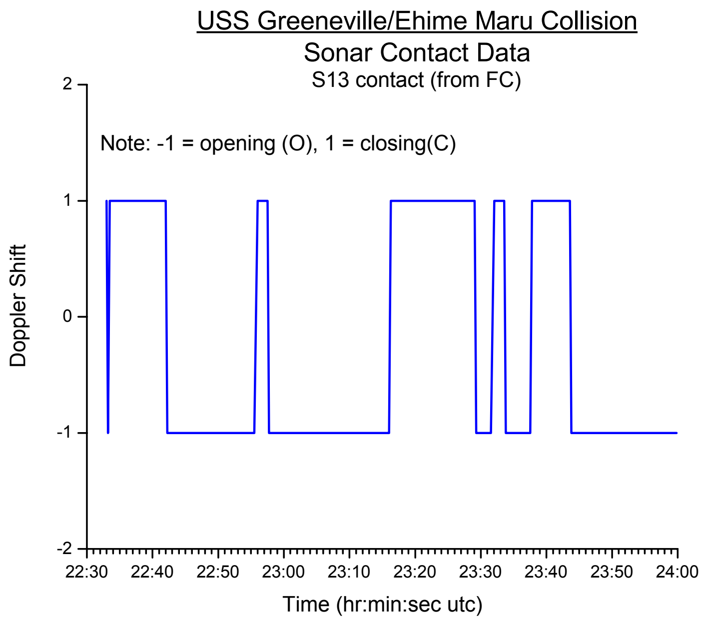


Figure 44: S13 FC Doppler shift

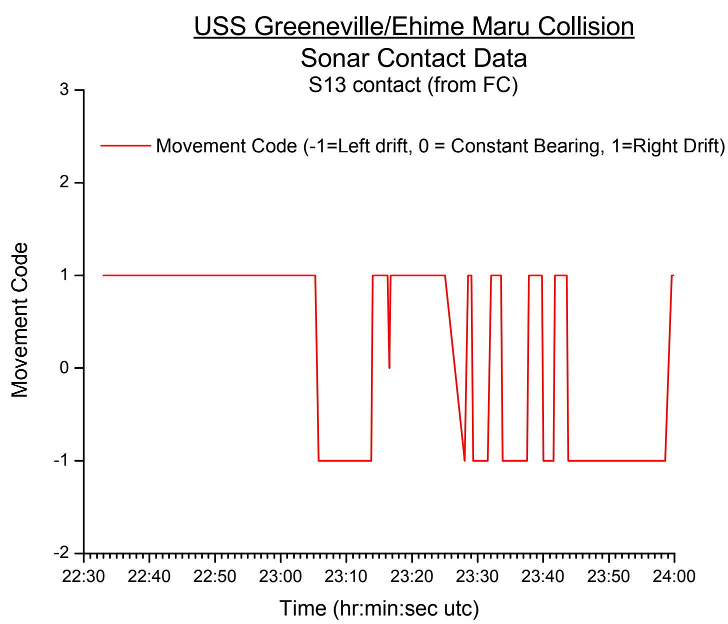


Figure 45: S13 Movement code

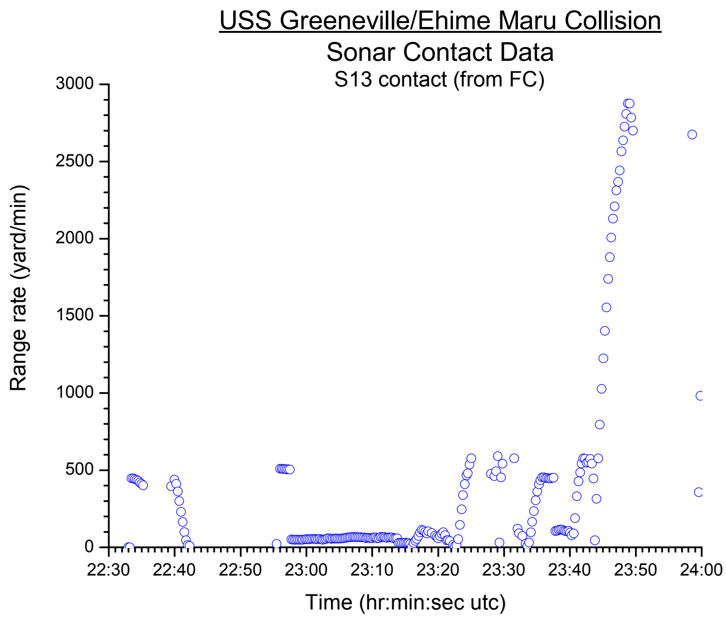


Figure 46: S13 FC range rate

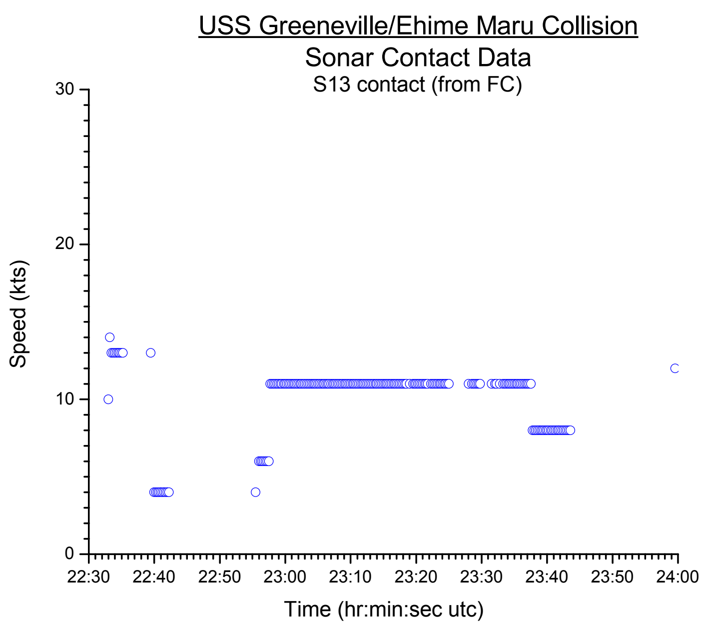


Figure 47: S13 FC speed solution

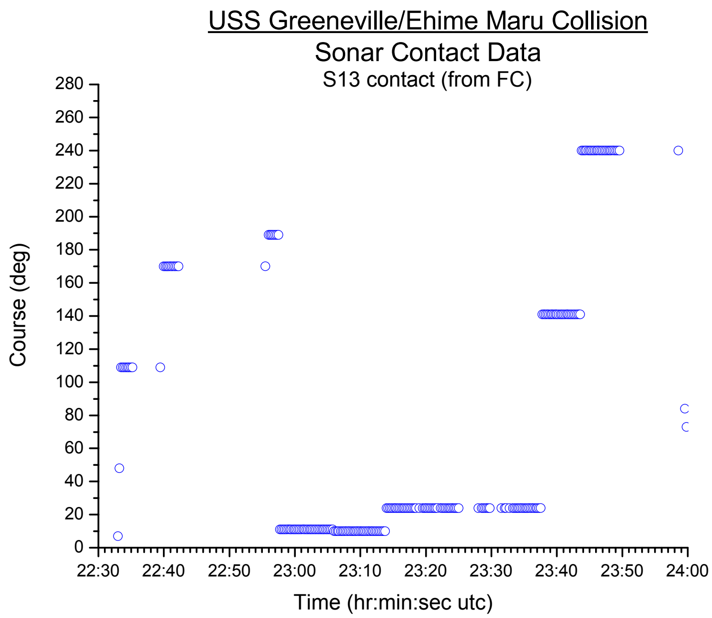


Figure 48: S13 course solution

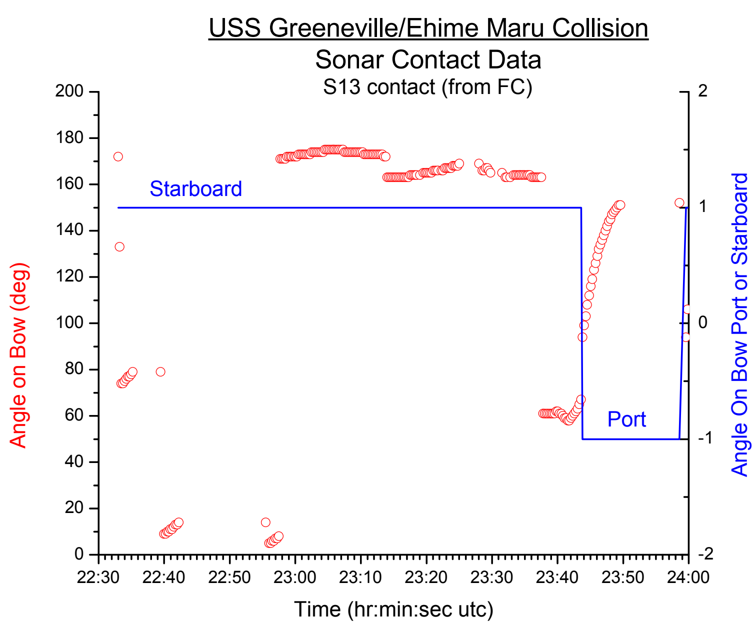


Figure 49: FC Angle on Bow

The following fire control parameters were unchanged from the initial contact with the Sierra 13 target till the contact was lost. Note that the Port/Starboard flag is invalid for spherical array contacts such as this.

PARAMETER	VALUE	MEANING
lsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	0	Not used
TrkString	FCS	
lsBRG	1	Automatically logged
PortSTRBDflag	P	Port (invalid)
lsMovement	1	Automatically logged
lsDE	0	Not used
lsSNR	0	Not used
lsSolutionSourse	0	Not used
lsRange	1	Automatically logged
lsCourse	1	Automatically logged
lsSpeed	1	Automatically logged
lsAOB	1	Automatically logged
lsRangerate	1	Automatically logged

Relative bearing recorded from sonar and true bearing recorded from the fire control system solution are presented in figure 50. A calculated true bearing developed from own-ship heading and sonar bearing is also presented. Note that calculated true bearing is invalid in the time periods that sonar bearing is not available.

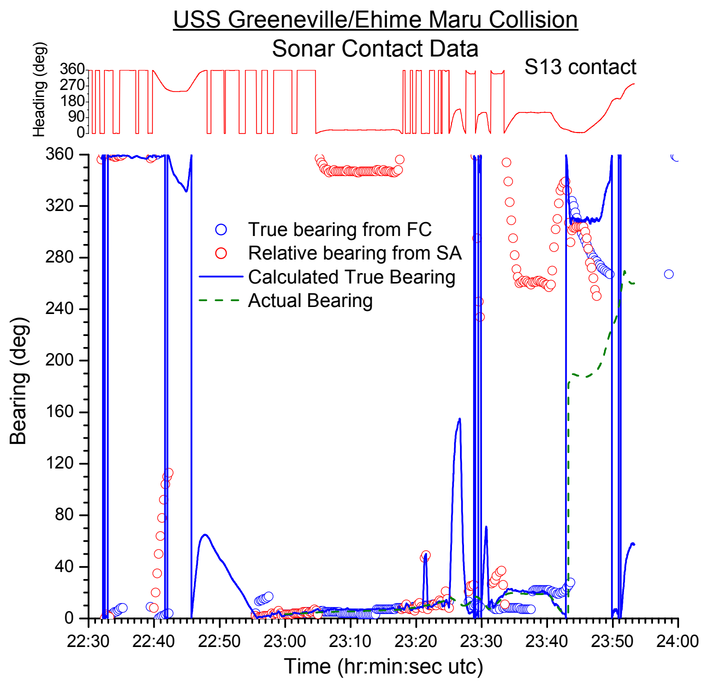


Figure 50: S13 bearing

Actual bearing and range to Sierra 13 was obtained from radar and own-ship position. Actual bearing is plotted against FC bearing in figure 51. Actual range is plotted against the fire control range solution in figure 52.

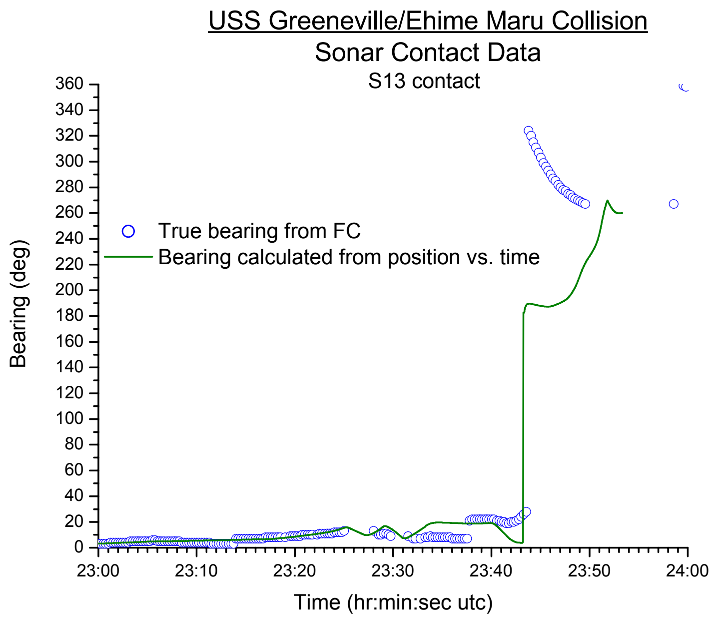


Figure 51: S13 bearing comparison

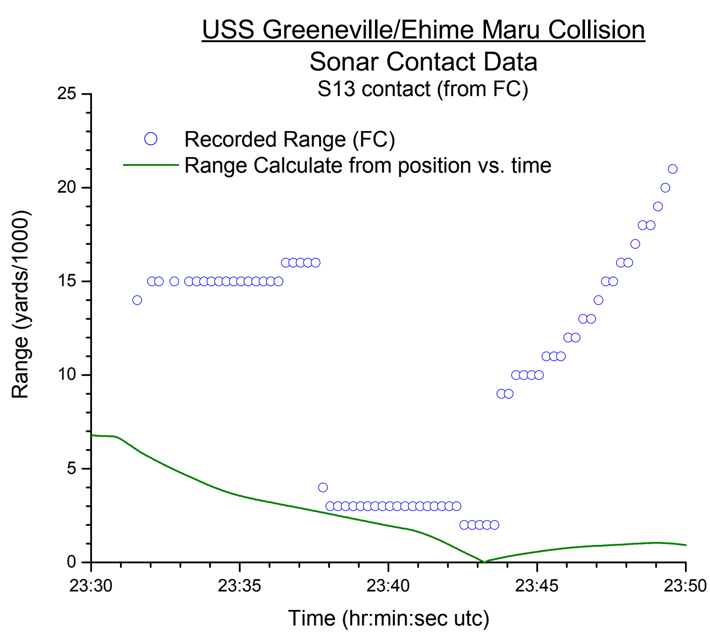


Figure 52: S13 range comparison

Sierra 14 Contact

Data recorded from sonar for Sierra 14 are plotted in figures 53 and 54. A plot of signal to noise ratio is presented in figure 53. The Doppler opening or closing flag for sonar is plotted in figure 54. This Doppler flag defaults to data from fire control unless manually entered by the sonar operator. Sonar bearing is plotted together with fire control bearing in figure 61.

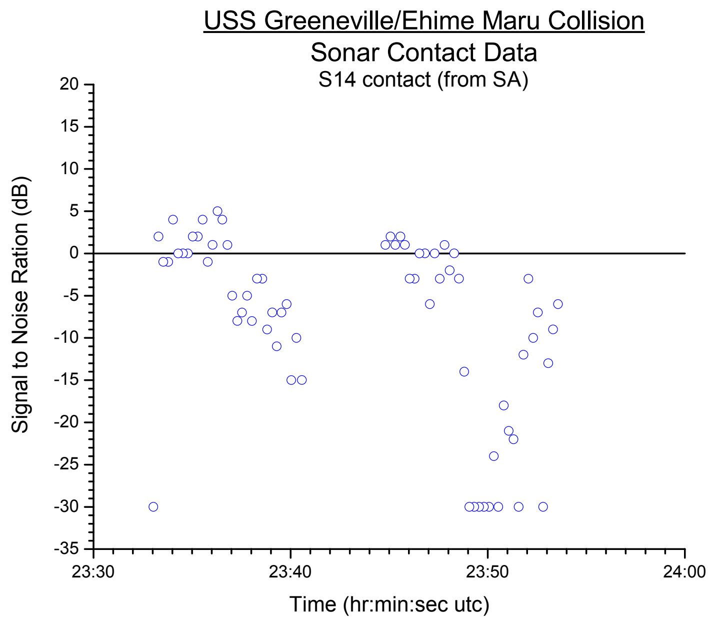


Figure 53: S14 signal to noise ratio

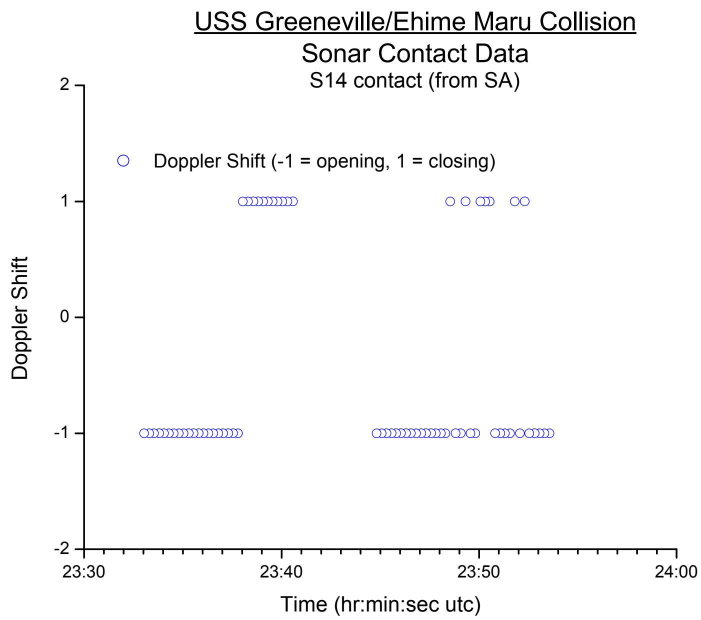


Figure 54: S14 sonar Doppler shift

The following data from sonar remained constant from the initial contact with the Sierra 14 target until the contact was lost. Note that DE defaults to zero. Thus the zero recorded value is an indication that the recorded DE is not valid. Also, TQI (Track Quality Indicator) defaults to "strong." The "strong" TQI is not an indication of track quality.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
LsSensor	1	Automatically logged
LsProcessor	1	Automatically logged
Processor	D	DIMUS
TrkString	D*	BSY – 1 Sphere PBB
LsBRG	1	Automatically logged
lsMovement	1	Automatically logged
MovementCode	M	Constant Brg rate
LsDE	1	Automatically logged
DE	0	Tracker's DE position
LsSNR	1	Automatically logged
TQI	S	Strong

Parameters from the recorded system fire control solution for the Sierra 14 target are plotted in figures 55 to 60. Fire control solution bearing is included in the bearing comparison in figure 61.

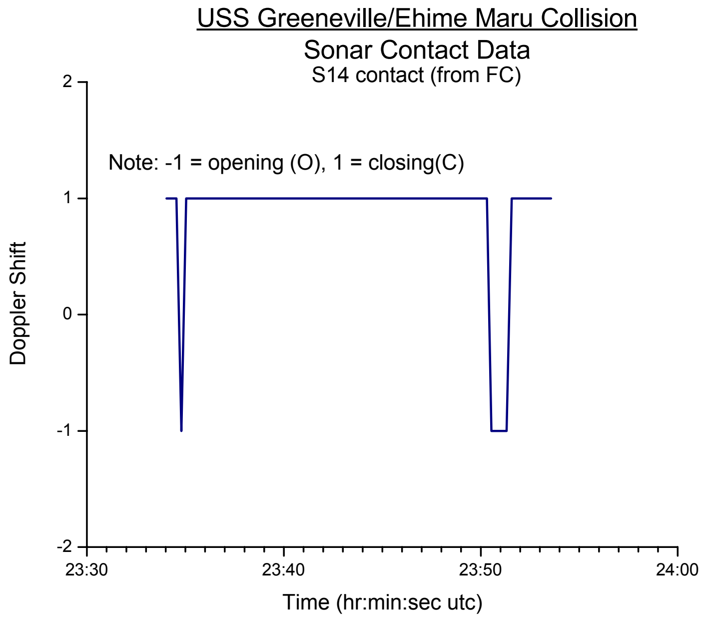


Figure 55: S14 FC Doppler

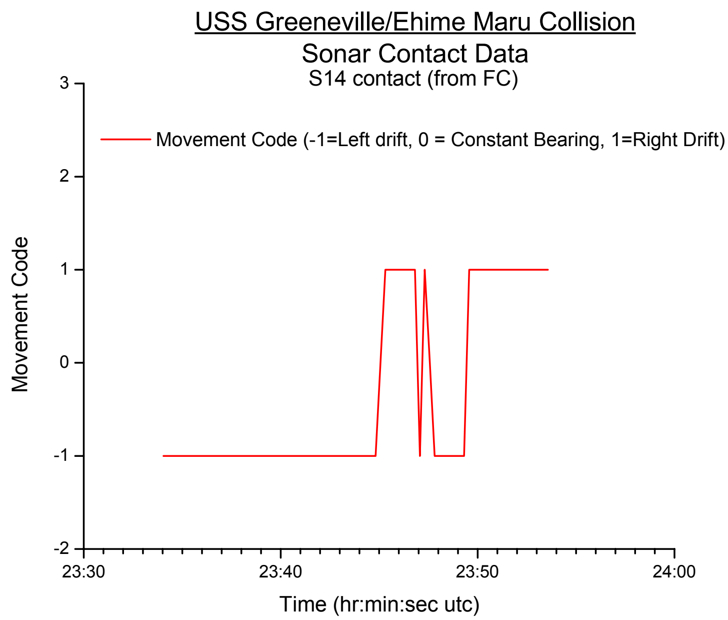


Figure 56: S14 Movement code

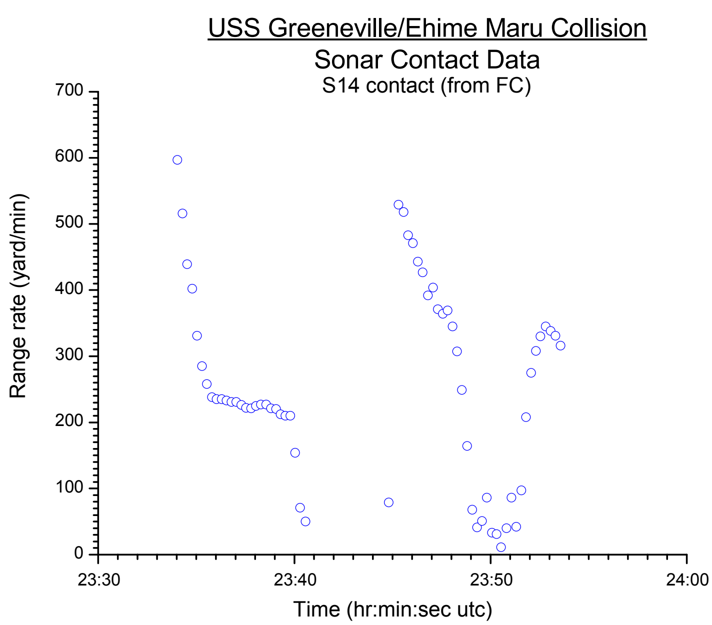


Figure 57: S14 FC range rate

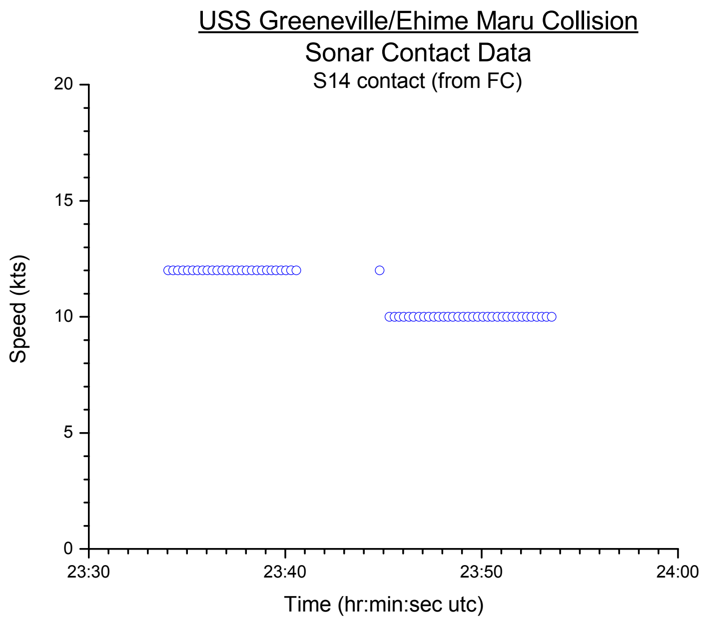


Figure 58: S14 FC solution speed

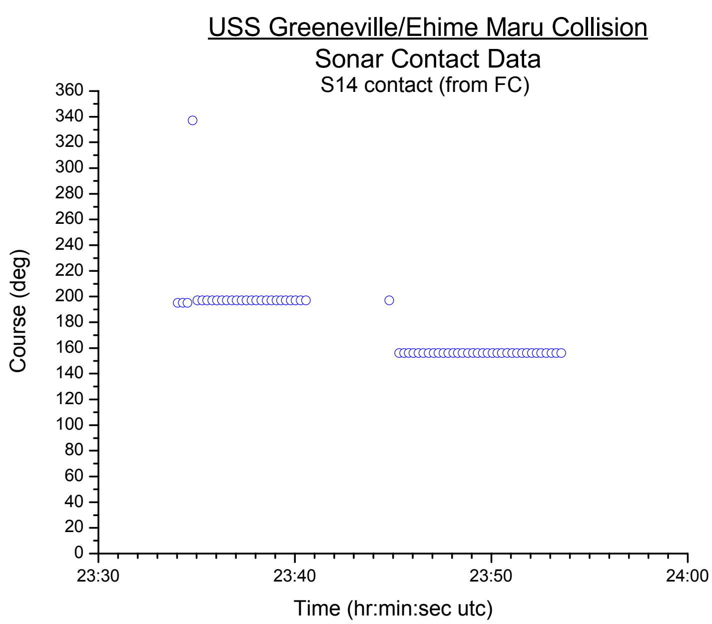


Figure 59: S14 FC solution course

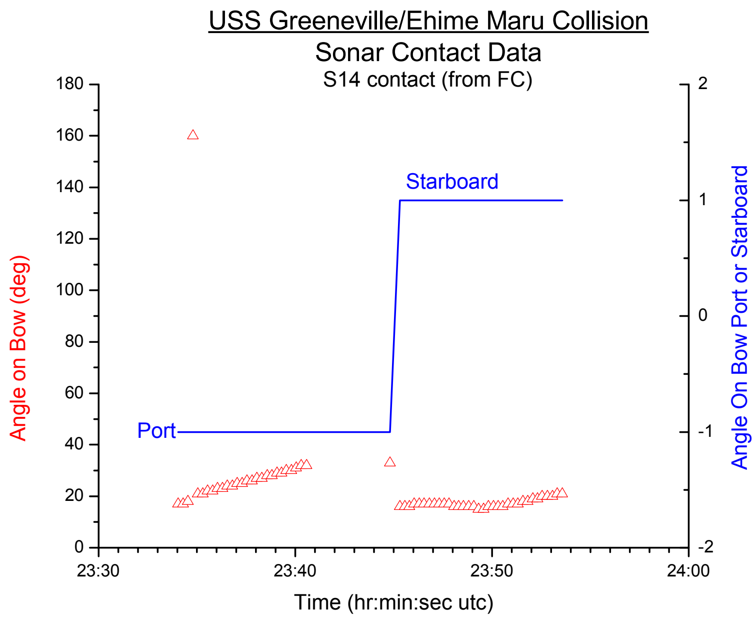


Figure 60: S14 FC angle on bow

The following fire control parameters were unchanged from the initial contact with the Sierra 14 target till the contact was lost. Note that the Port/Starboard flag is invalid for spherical array contacts such as this.

PARAMETER	VALUE	MEANING
LsSierra	1	Automatically logged
sClassSymbol	1	Automatically logged
ClassSymbol	6	Unknown Surface
lsSensor	1	Automatically logged
lsProcessor	0	Not used
TrkString	FCS	
lsBRG	1	Automatically logged
PortSTRBDflag	P	Port (invalid)
lsMovement	1	Automatically logged
lsDE	1	Automatically logged
lsSNR	0	Not used
lsSolutionSourse	0	Not used
lsRange	1	Automatically logged
lsCourse	1	Automatically logged
lsSpeed	1	Automatically logged

lsAOB	1	Automatically logged
lsRangerate	1	Automatically logged

Relative bearing recorded from sonar and true bearing recorded from the fire control system solution are presented in figure 61. A calculated true bearing developed from own-ship heading and sonar bearing is also presented. Note that calculated true bearing is invalid in the time periods that sonar bearing is not available.

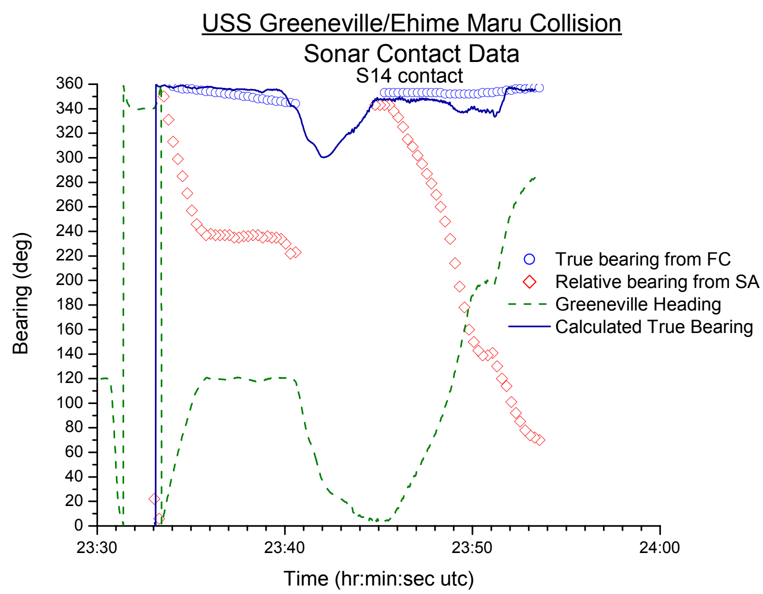


Figure 61: S14 bearing

Actual bearing and range to Sierra 14 was obtained from radar and own-ship position. Actual bearing is plotted against FC bearing in figure 62. Actual range is plotted against the fire control range solution in figure 63.

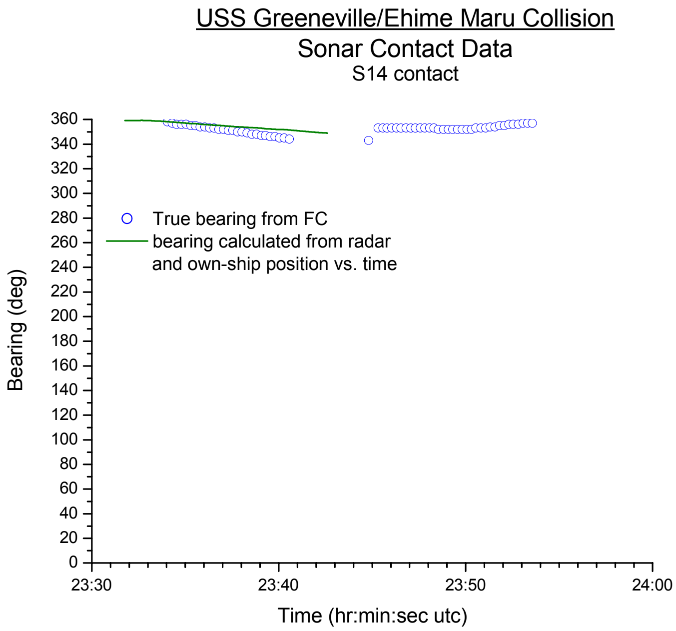


Figure 62: S14 actual vs. FC bearing

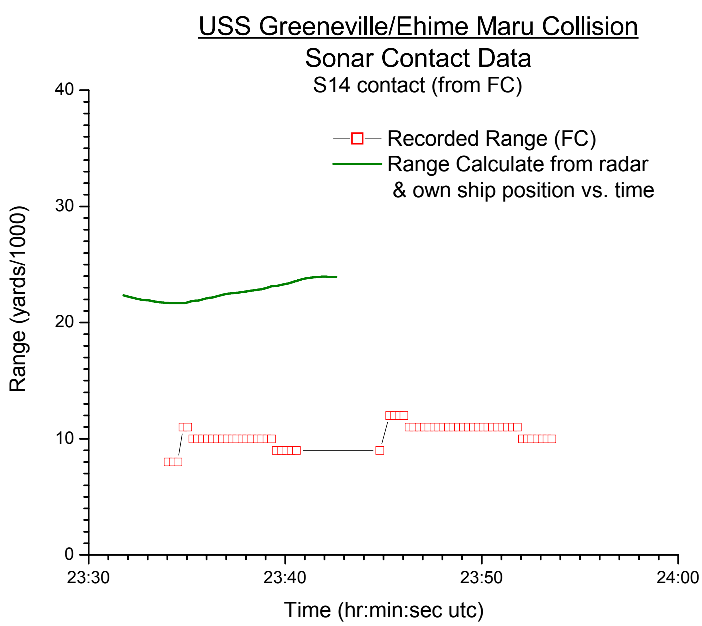


Figure 63: S14 actual vs. FC range

Summary

Radar data shows that the Ehime Maru was on a heading of 166 deg at 11 Kts prior to the collision. The fire control system solution at the time the Greeneville reached periscope depth was 3000 yards. Although the solution course was wrong, the solution distance matched the actual range at this time developed from the accident reconstruction.

Dennis Crider
National Resource Specialist
Aircraft Simulation